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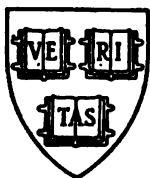
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MEMOIRS
OF THE
GEOLOGICAL SURVEY
OF
GREAT BRITAIN,
AND OF THE
MUSEUM OF PRACTICAL GEOLOGY.

THE GEOLOGY OF
THE WARWICKSHIRE COAL-FIELD
AND THE
PERMIAN ROCKS AND TRIAS OF THE SURROUNDING
DISTRICT.

BY
H. H. HOWELL, F.G.S.

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NOTICE.

THE following Sketch of the Geology of the Warwickshire Coal-field and the surrounding district will be found, I trust, to be of use to the proprietors of the district, not only as developing the mineral resources actually in work, but specially in indicating the probable range and extent of the Coal-formation beneath the red deposits, whether they be of the age of the Permian rocks or New Red Sandstone.

RODERICK I. MURCHISON,
Geological Survey Office, Director-General.
Jermyn Street, S.W., Aug. 1859.

THE district to which the following Memoir refers was surveyed by Mr. Howell and myself between the years 1851 and 1854, during the life of Sir Henry De la Beche, the late Director-General. The map of the Coal-field and all the sections are by Mr. Howell, and I only occasionally assisted in tracing its boundary faults, and in mapping parts of the surrounding Formations. I also first determined the true age of the Permian rocks of this area, and helped, when the other duties of the survey would permit, to map these strata, and a considerable part of the New Red Sandstone and Marl. The whole, as usual, was superintended by myself.

A. C. RAMSAY,
Geological Survey Office, Local Director.
August 1859.

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to the
GEOLOGICAL SURVEY MAP
of the
WARWICKSHIRE
COAL FIELD.
By H.H. Howell, F.G.S.

Scale 3 Miles to an Inch

0 1 2 3 4 5 Miles

62 N.E.
62 S.E.

63 N.W.
63 S.W.

Sect. Sheet 40
N° 2 P.L.I.

54 N.E.

55 N.W.



Alluvium



Red Marl
and
Lower Rhyolite Sandstone
(Kuper)



Pebble Beds
(Dunder)



New Red
Sandstone



Marl and Sandstone
with Colicoreus
conglomerate

Permian



Limestone
coal crops

Coal Measures



Inclined
+ Horizontal
White Limes
Faults

Milstone Grit

Inclined
+ Horizontal
White Limes
Faults

Strata



W. Done del.

WARWICK

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J. W. Lewis

THE GEOLOGY OF THE WARWICKSHIRE COAL-FIELD AND THE PERMIAN ROCKS AND TRIAS OF THE SURROUNDING DISTRICT.

By H. H. HOWELL, F.G.S.

CHAPTER I.

PHYSICAL FEATURES OF THE DISTRICT, AND GENERAL DESCRIPTION OF THE ROCKS.

THE area included within the district to which this memoir refers is contained within the limits of the quarter sheets of the survey 62 N.E. and S.E., 63 S.W., 54 N.E., 53 N.W., and part of 63 N.W., extending northwards about 4 miles north of Lichfield, between Brereton and Barton-under-Needwood, and on the west, south, and east as far as Birmingham, Warwick, and Rugby. The greater portion of this area is in the county of Warwick, the remainder being within the adjacent counties of Staffordshire and Leicestershire.

The most prominent physical features of the district are formed by the Carboniferous and Permian formations, which form a tract of country slightly elevated above the plain of New Red Sandstone which surrounds it. The most marked of these features occurs between Nuneaton and Merevale, where the lower Carboniferous rocks form an abrupt ridge rising to an average height of 500 feet above the sea, the north-east side being bounded by a fault, beyond which the New Red Marl stretches in a gently undulating plain, toward Charnwood Forest and Leicester, and the escarpment of the Lias between the latter place and Rugby.

On the west side of this tract the Carboniferous and Permian formations form a rising ground, sloping to the west. This is also bounded by a fault, beyond which the New Red Marl extends towards Birmingham.

The Permian rocks at one point, viz., at Corley, rise to a height of 625 feet above the sea.

Another well-marked feature occurs in the neighbourhood of Warwick, where, on account of the north and south fault which runs to the west of that town, the Lower Keuper Sandstone is

thrown to a much higher level than the Red Marl, and forms an abrupt ridge along the east side of the fault, which runs through the low ground on the west side of Warwick to Kenilworth. Between Warwick and Coventry the Lower Keuper sandstone forms a low escarpment along its boundary with the Permian rocks.

The principal rivers are, the Tame, which flows east from Birmingham to near Coleshill, at which place it suddenly bends round, and taking a northerly course through Tamworth, falls into the Trent at Alrewas, about five miles north-east of Lichfield. The Avon, from Rugby, flows south-west to Leamington and Warwick, and eventually joins the Severn at Tewkesbury. The water-shed in this district may be said roughly to run in a line between Bromsgrove Lickey, Kenilworth, Meriden, Corley, Bedworth, and Shilton. On the north of this line the drainage of the country falls into the Tame and Trent, and thus flows into the German Ocean, and that on the south side into the Avon and Severn, and so into the Bristol Channel.

The following formations enter into the structure of this district.

Stratified rocks	- { 1. The Lias. 2. The Trias or New Red Sandstone. 3. The Permian rocks. 4. The Coal-measures.
Igneous rocks	- Greenstone.

The Warwickshire coal-field, where it rises to the surface, occupies a long, narrow strip of country, which commences on the south near the Hawkesbury railway station, and from thence strikes north-east to Baddesley Ensor, maintaining an average width of from one to two miles. At Baddesley Ensor it suddenly widens to about four miles from east to west, and continues about the same width as far north as Shuttington.

The rocks in and around this area, in ascending order, belong to the Palæozoic and Mesozoic periods. The Palæozoic is represented by the Carboniferous formation, consisting of Millstone Grit and Coal-measures, and by a part of the Permian strata; and the Mesozoic by the New Red Sandstone and the Lias.

The Millstone Grit lies on the east side of the coal-field, between Nuneaton and Atherstone. The Coal-measures succeed this grit on the west, and consist of the usual assemblage of strata characteristic of that formation, together with one bed of limestone.

The Permian formation, which immediately overlies the Coal-measures, is sometimes apparently conformable to them, and is composed of alternating beds of white, purple, and red sandstone and marl. The sandstones in some places become hard calcareous breccias and conglomerates, which generally do not continue in regular beds over large areas. There is, however, one

mass of conglomerate which is continuous for a considerable distance, and forms a marked horizon about the middle of the Permian beds. This conglomerate is often calcareous, being principally composed of Carboniferous Limestone pebbles cemented together in a calcareous matrix.

The New Red Sandstone in this district is not so extensively developed as in other parts of the country, in Worcestershire, Shropshire, and Cheshire; some of the subdivisions which occur in those counties being absent. There are, however, four distinct subdivisions, viz., the conglomerate beds at the base, and the Upper red and mottled sandstone, belonging to the Bunter series; and the Lower Keuper sandstone or waterstones overlaid by the New Red Marl, containing the Upper Keuper sandstone. When we come to examine the New Red Sandstone more in detail, we shall find that even in this district the whole of these subdivisions are not constant, but thin away rapidly from west to east.

The Lias in this district belongs entirely to the lower beds of that formation, consisting of alternate layers of blue limestone and clay. It lies conformably on the Keuper, marls, and on account of the limestone beds just above the junction, the boundary is generally well marked by an abrupt escarpment, formed by the outcrop of those beds above the softer marls.

CHAPTER II.

CARBONIFEROUS ROCKS.

The Millstone Grit.

THIS rock, the lowest part of the Carboniferous formation seen in this district, occupies a high ridge between Nuneaton and Atherstone, about two and a half miles in length, by half a mile in width. It consists of a hard silicious quartz rock, with thin bands of interstratified shale, the whole exceedingly altered, and being traversed along the strike by intrusive lines of greenstone. Two of these trap dykes can be seen in actual contact with Millstone Grit; one in a quarry by the canal near Tuttle Hill at the north-west end of the town of Nuneaton; and the other, which is not more than a yard in thickness, is exposed in a quarry near Hartshill. There is also another mass of greenstone below these two, but at no place can its junction with the Millstone Grit be seen. It lies between the lowest bed of that rock, exposed at the surface, and the boundary fault of the coal-field, which brings the New Red Sandstone against the Carboniferous rocks. The greenstone is probably intrusive in the same way as

the others, although we have no positive means of telling, on account of the great fault just mentioned, which cuts off the whole of the Carboniferous rocks on the north-east, and prevents us from ascertaining what lies beneath the line of greenstone.

The Millstone Grit has an average dip to the south-west at an angle of from 30° to 40° , passing under the ordinary Coal-measures which lie conformably upon it. No fossils have ever been found in it, and from the strong resemblance it bears to the quartz rock of Bromsgrove Lickey, it was formerly classed as part of the Silurian series;* but from the fact of the complete conformity of the Coal-measures upon it, and the occasional streaks of Coal-measure looking shale with which it is banded, the evidence is more in favour of its belonging to the Carboniferous formation. It is extensively quarried between Nuneaton and Atherstone for road material, and is used for that purpose for many miles round. The great number of joints which intersect the rock render it easily worked, and it breaks up into innumerable cuboidal fragments. At Tuttle Hill it was formerly worked for manganese, which was found in the joints and fissures of the rock, but no works are at present in operation, the mineral not being in sufficient quantities to render it profitable. The whole mass of the rock has a pink tinge, which is probably caused by manganese disseminated through it.

The Coal Measures.

The Coal-measures of Warwickshire consist of alternating beds of sandstone, shale, indurated clays, ironstone, and beds of coal, with one well-recognised bed of limestone in the upper part of the series, about 150 feet below the base of the Permian strata. Of these the limestone and the coals are the most constant over the whole field, the other strata, especially the sandstones, being very variable in thickness.

This will be seen by referring to the published Vertical Sections, Sheet 21, of this coal-field, and by comparing the pit sections at the north end at Tamworth, Polesworth, and Baddesley, with those at the south in the neighbourhood of Bedworth. This will be explained more in detail in a subsequent part of the Memoir.

The Coal-measures lie in a kind of long synclinal curve or trough, the east and west sides of which are bounded by faults. The eastern edge runs in a nearly north and south line from Bedworth to Polesworth, the western outcrop where exposed at the surface running from north to south, between Tamworth and Kingsbury, and there can be no doubt that this basin-shaped form is continued under the Permian beds still further south. The greatest width of the Coal-measures at the surface is not more than four miles.

* Trans. Geol. Soc., vol. ii. p. 237.

The workable seams of coal all lie about the middle of the series, having a great thickness of barren measures both above and below. It is only in the neighbourhood of Hartshill that the lowest beds can be seen. By drawing a line at right angles to the strike of the beds we are enabled to estimate with tolerable accuracy the total thickness of the whole formation, from the base of the Permian rocks to the top of the Millstone Grit. This, as shown in the section, No. 2, sheet 51, gives a total thickness of Coal-measures of about 3,000 feet, the lowest productive bed of coal known being about 1,050 feet below the base of the Permian rocks.

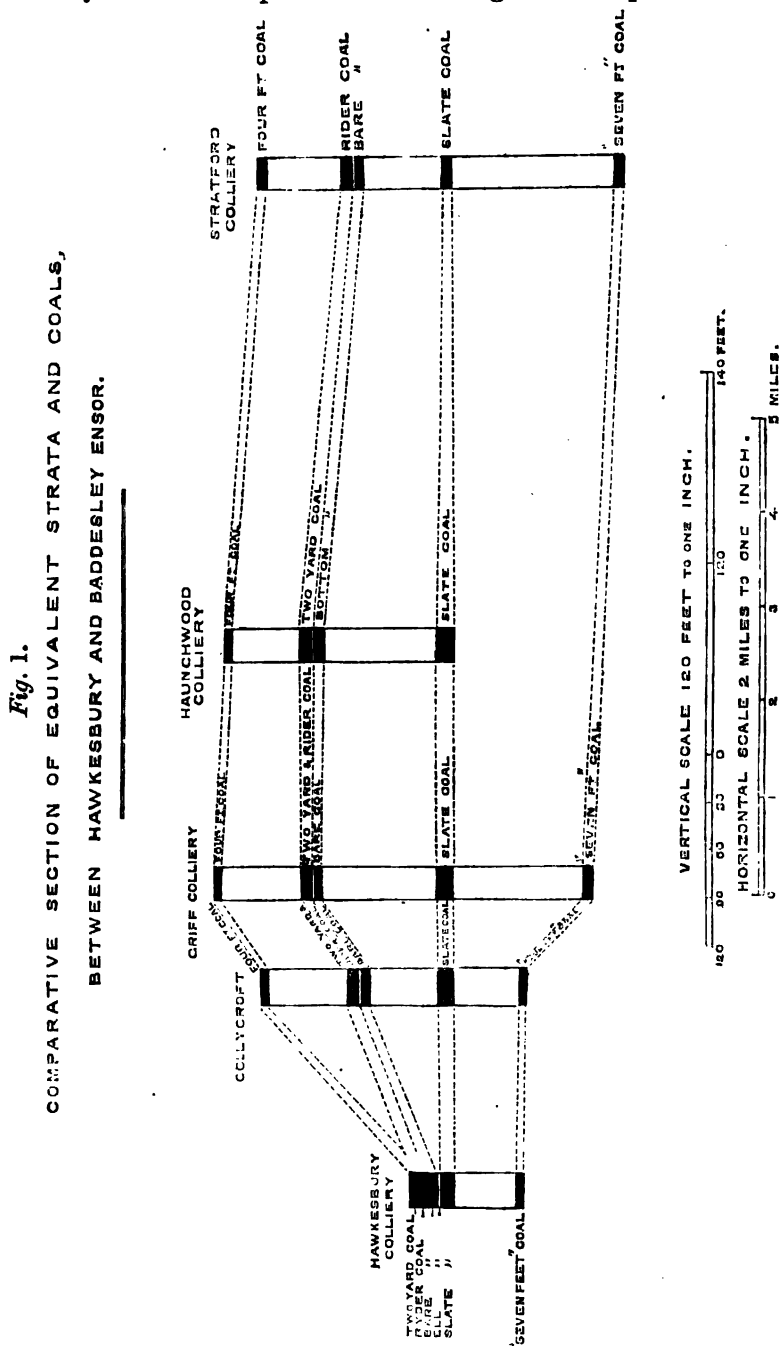
On the top of the Millstone Grit, and resting conformably upon it, is a thick series of rocks, consisting principally of red shales, with intrusive lines of greenstone, like those which occur in the Millstone Grit. These shales lie between the lowest known bed of coal and the Millstone Grit, and attain a thickness of about 2,000 feet. They are mostly of a deep red colour, and where in contact with the greenstone are much altered. It is in these shales that the Manganese which was formerly wrought at Hartshill Hays is found, and the red colour of the rocks is probably due to the presence of that mineral disseminated through them.

On the south the same beds are first seen in Griff Hollow, where Manganese was also formerly obtained from them. From this point they stretch northward, following the strike of the coal-field through Chilvers Coton, where they are exposed in the Railway cutting. They next appear at the surface about $\frac{3}{4}$ of a mile west of Nuneaton, at the west end of Wash Lane, where Manganese was also formerly wrought, and from thence they strike in a north-westerly direction, and may be traced almost uninterruptedly through Camp Hill, Hartshill Hays, and Atherstone Outwoods, to Merevale Park, interbedded with lines of intrusive greenstone, afterwards to be described. No fossils have ever been obtained from them, but their position in the carboniferous series is well defined at Hartshill, lying between the Millstone Grit and the productive Coal-measures, as shown in Horizontal Section, No. 2, sheet 51, and in the reduced sections, No. 5, pl. 1.

The workable seams of coal in this field are five in number, one of these being double, and only separated by a thin bed of fire-clay. They are not, however, constant in thickness, and in some cases thin away altogether.

By referring to the vertical sections, sheet 21, it will be seen that the strata which separate the coals also vary much in thickness. In the south part of the coal-field in the neighbourhood of Bedworth and Hawksbury, the whole of the coals come together and form one thick seam with thin partings of fire-clay, whereas in the north part in the neighbourhood of Tamworth, Polesworth, and Baddesley, the same beds of coal are widely separated, the intermediate strata of sandstones and shales having gradually thickened out. This gradual separation of the coals by the thickening out of the intervening strata, will be understood by comparing the pit sections of the coal-field from south to north, as given in the Ver-

tical Sections, sheet 21, and it is brought more prominently before the eye in the comparative section, Fig. 1. The pit section of



the old Wykin colliery is the most southern of which any record has been taken. It is section No. 5 in the sheet above mentioned,

and in it five workable coals are given, viz., the Two yard, Bare, Rider, Ell and Slate coals. The Two yard and Bare coals are separated by a thin bed of fire-clay, locally called "Lam;" and the Bare, Rider, and Ell coals have according to this section no intermediate beds, but form one coal. They are, however, never wrought as such, and probably are separated by very thin partings, part of one of the coals being generally left for the roof. Between the Ell and Slate coals there is, according to the section, a bed of blue marl (probably a fire clay) 10 feet thick.

The next colliery proceeding northwards, of which a section is given is Hawksbury, No. 13 in the same sheet. We have here the same order and number of coals as at Wykin, but there is a slight alteration in the partings which separate them. A more accurate and detailed section of the Hawksbury coals is given in section, No. 10, viz. —

			FT.	IN.
	Two yard coal	-	-	6 0
	Black marl (fire-clay)	-	-	0 7
	Bare coal	-	-	2 0
	Rider stone	-	-	0 6
	Weller coal	-	-	0 6
	Rider coal	-	-	4 0
Ell coal.	{ Ell coal tops	-	-	1 8
	{ Parting	-	-	0 10
	{ Ell coal	-	-	3 11
Slate coal.	{ Fire clay	-	-	1 0
	{ Coal	-	-	2 1
	{ Bat	-	-	0 3
	{ Coal	-	-	4 6
	{ Fire-clay	-	-	2 0
	{ Black marl	-	-	1 0
	{ Lady coal	-	-	3 0
	Binds and Ironstones	-	-	32 7
	Seven-feet coal	-	-	4 6

It will be seen from this that the thickness of the measures between the coals are much about the same as at Wykin, whatever discrepancies there is, probably arising from this section being taken with more care and in greater detail.

The coals also occur in the same order and much about the same thickness in the Bedworth colliery, which comes next north of Hawksbury, and in all of these pits it will be seen that the coals form nearly one thick seam, with thin partings of fire-clay.

North of Bedworth we find that the same coals become separated, and the partings, which are only a few inches thick at Bedworth, Hawksbury, and Wykin, gradually swell out and attain many yards in thickness. So much is this the case that were it not for the regularity of the outcrop of the coals on the east side of the field, by which we are enabled to trace them in a continuous line on the surface from south to north, it will be seen from the following details that it would be almost impossible to identify the coals at Baddesley and Polesworth with the same seams at Bedworth.

The first colliery north of Bedworth of which I have a section is at Griff, where in the engine pit we have the following strata:—

				FT.	IN.
Four-feet coal	-	-	-	-	3 0
Intermediate measures	-	-	-	-	51 0
Two yard coal	-	-	-	-	6 0
Rider coal	-	-	-	-	2 0
Parting	-	-	-	-	9 0
Bare coal	-	-	-	-	4 2
Intermediate measures	-	-	-	-	72 0
Slate coal	-	-	-	-	10 0
Intermediate measures	-	-	-	-	84 0
Seven-feet coal	-	-	-	-	5 9

From this section it will be seen that the thickness of strata between the Two-yard, Rider, and Bare coals, and the Slate coal, and between the Slate and Seven-feet coals, has increased enormously. The Four-feet coal, which is given as the first in this section, is not known at Bedworth and the collieries south of that place, having apparently thinned away. In the south part of the Griff colliery, at Collycroft, the intermediate measures between the Bare and Slate coals and the Slate and Seven-feet coals respectively are 14 yards thick.

At Haunchwood colliery, near Nuneaton, which is about two miles north north-west of Griff, we have not a complete section of the coals, the pit having only been sunk to what is called there the "Bottom coal" at the time this survey was made. This coal represents the Rider or Bare coal of Griff. A detailed account of the strata in Haunchwood colliery is given in the published Sheet of Vertical Sections, No. 21. From this section it appears that the thickness of the strata between the Four-feet coal and the Two-yard coal is not so great as at Griff; the difference, however, is not more than 10 feet, as will be seen from the following section:—

				FT.	IN.
Four-feet coal	-	-	-	3	4
Intermediate measures	-	-	-	42	9
Roof coal	-	-	-	1	0
Fire-clay and bat	-	-	-	1	3
Coal	-	-	-	6	6
Parting	-	-	-	0	8
Coal	-	-	-	6	6

} Two-yard coal.

Between Haunchwood and the next colliery further to the north-west, there is a considerable distance, along which we have no detailed account of the thickness of the coals and the intermediate measures, no collieries being at present in operation between Haunchwood and Baddesley. At the latter place we have detailed sections of the measures, two pit sections of which, viz., the Speedwell pit, Baddesley, and the Stratford pit, Baxterley, are given in the Sheet of Vertical Sections before mentioned. From

these it appears that the following is the order of the coals and the thickness between each bed, viz. :—

				FT.	IN.
Four-foot coal	-	-	-	4	4
Intermediate measures	-	-	-	49	2
Rider coal	-	-	-	8	6
Parting	-	-	-	0	9
Bare coal	-	-	-	5	6
Intermediate measures	-	-	-	58	0
Slate coal	-	-	-	4	6
Intermediate measures	-	-	-	102	0
Seven-foot coal	-	-	-	5	6

At Polesworth the thickness of strata between the seams of coal does not differ much from that at Baddesley, although the Rider and Bare coals are altogether wanting. According to the pit section given in the Vertical Section, Sheet 21, the following is the order of the coals and the thickness of the strata between them :—

				FT.	IN.
* Ell coal	-	-	-	4	6
Intermediate strata	-	-	-	96	0
Slate coal	-	-	-	7	3
Intermediate strata	-	-	-	101	0
Seven-foot coal	-	-	-	6	0

I shall now proceed to describe in detail the position of the five coals, viz., the Four-foot, Rider and Bare, Slate, Seven-foot, and Bench coals, where they crop out to the surface on the east side of the field, commencing at the north-end, near Polesworth, and following them south to Wykin, near Coventry, where they are concealed by overlying New Red Sandstone, which lies unconformably upon them.

By referring to the Index map, or to the published map, 62 N.E., it will be seen that the coals where they appear at the surface at the north end, near Polesworth, are cut off by the boundary fault of the coal-field on the east side, which brings the Permian rocks against the Coal-measures. This fault was proved in working the Seven-foot coal in a pit, which was sunk close to the barn, on the east side of the Railway cutting between Polesworth station and the bridge over the Railway between Polesworth and Waverton. The coal was here 60 yards deep, and was wrought up to the "Red Rock fault," which cut off the coals altogether to the east. The Four-foot, Slate, and Seven-foot coals crop out in the Railway cutting between Polesworth station and the bridge, and the Bench coal on the south-east side of the bridge. The measures are much broken and disturbed where exposed in this cutting, and have a general dip to the west at an angle of 45° to 50°, and the unusually high angle at which the strata are inclined, is accounted for by the close proximity of the boundary fault, which here runs along the east side of railway. Proceeding south, the crops of the

* Represents the Four-foot coal of Baddesley.

Four-feet, Slate, Seven-feet, and Bench coals can be traced by means of the old surface workings towards Birch Coppice. An old pit, now filled up, close to where the turnpike road between Tamworth and Atherstone crosses the canal a little to the east of Polesworth, was 110 yards deep to the Seven-feet coal, and 170 yards to the Bench coal.

The outcrop of the Seven-feet coal can be traced by means of the old workings along the west side of the wood called the "Hollies," and that of the Bench coal a little to the east of this within the wood. All the coals have formerly been worked more or less at the crop, and they dip nearly due west at a small angle. The Seven-feet coal is at present being worked at Mr. Shaw's colliery, at the Whitehouse, near Polesworth, where it is 170 yards deep, the depth to the Four-feet coal in the same pit being 60 yards. The dip of these coals here is due west at an angle of 16° . This angle does not, however, continue for any great distance further west, for where the coal has been worked to "the deep," the inclination becomes gradually less, and there is no doubt that still further west, at the middle of the trough, the coal would be found quite horizontal.

On the east side of the "Hollies," beyond the crop of the Bench coal, the strata form a small anticlinal curve, and the coals set in again, having a dip to the east. This is important, for it is the only part on the east side of the coal-field where we find positive evidence of the same coals rolling over and dipping to the east, as shown in the reduced section, No. 1, pl. 1. This section, on a scale of two inches to a mile, is taken across the north part of the coal-field between Glascote and Polesworth, between which places the coals lie in the form of a trough or basin, and on the east side of the section it will be seen that the Seven-feet and Bench coals after rising to the surface, roll over and dip towards the east, till they are cut off by the boundary fault of the coal-field, which brings the New Red Sandstone against the upper part of the Coal-measures. The coal has never been worked to any extent on this easterly dip, being much broken and faulted. Attempts were, however, made to work the Seven-feet coal by the side of the lane between Polesworth and Dordon, and the bed was followed in from the crop for a considerable distance, but was found to be so much shattered by small faults as to be altogether unprofitable. These faults were described to me by Mr. Scarrot, the manager of the colliery at Polesworth, as continually throwing the coal down to the east, sometimes many yards, and all running parallel with the boundary fault of the coal-field. It was in consequence of these numerous dislocations that the working of the coal was abandoned, as it was considered that they would most probably continue till the great boundary fault was reached, which would throw the coal down on the east to an unknown depth beneath the New Red Sandstone.

We will now follow the coals from the "Hollies" through Birch Coppice. It will be seen by referring to the map 62 N.E. (and the index), that the outcrop of another coal lying between

the Four-feet and Slate coals, is laid down at Birch Coppice. This is a double coal, separated by a thin band of fire-clay, the upper bed being called the Rider, and the lower bed the Bare coal. It is not known to exist on the east side of the field further north than Birch Coppice, and from this point it is continuous all the way south to the end of the coal-field at Wyken. Like all the other coal beds, the double coal was formerly extensively worked in Birch Coppice, as is evident from the numerous old pits to be seen there.

As the workings here have been some time abandoned, I could not obtain any very accurate information as to the exact point where the Rider and Bare coal disappeared, or the way in which this "double coal" terminated; but as far as I could make out from the description given me of the last workings by Mr. Scarrot of Polesworth, there was no large fault, using that term in its correct sense, but the place of the coal seems to have been taken by a bed of fire-clay; and according to the accounts I obtained from the old miners, the coal terminated quite abruptly, the strata, however, not being shifted up or down. That it was not a *slip* fault was proved by the other coals, both above and below, being found to continue further north without any interruption.

Proceeding from Birch Coppice in a south-easterly direction, the outcrop of the coals can be traced without interruption as far as Monk's Park, about 2 miles south-west of Atherstone. The whole of the coals have been wrought more or less in former times, and the old crop pits can be distinctly traced through Baddesley Rough and Grendon Wood.

The Seven-feet and Rider and Bare coals are at present being worked at Baddesley on Mr. Dugdale's property. Detailed pit sections of these collieries are given in the Vertical Sections, Sheet No. 21, and were communicated to me by Mr. Pogmore of Baddesley colliery, who, in the most liberal spirit, also gave me every assistance that I needed while making the survey of this coal-field. The Coal-measures at Baddesley are entirely free from any large faults, though there are sometimes a few "hitches" throwing the coal up or down, but too small to be drawn with accuracy on the one-inch scale of map. A new pit has lately been sunk on Baxterley Common, the property of Mr. Dugdale, who is also proprietor of the Baddesley collieries. This pit, a detailed section of which is given in the Vertical Sections, Sheet 21, is at present by far the deepest in the coal-field. The section commences in the Coal-measures a very short distance below the lowest bed of the Permian rocks, passes through the limestone which lies in the upper part of the Coal-measures, and has been carried down to the Bench coal; so that in this pit we have very nearly a complete section from actual measurement of the Coal-measure strata, from the base of the Permian rocks down to the lowest workable coal.*

* I may mention here that it is the common and unreasonable opinion of the working colliers in this coal-field that there is no coal under the limestone. The section of this pit is a practical proof that that opinion is wrong. Whilst in the neighbourhood, during the sinking of this pit, I was frequently told that no coal would be found, because they had commenced above the limestone.

By comparing this section with the Speedwell pit in Baddesley colliery, it will be seen that on the whole they agree, although in some of the individual beds there are differences; for instance, the Seven-feet coal in the Baxterley section is much thinner and not so good in quality as at Baddesley, and on the other hand, the Rider and Bare coals are much thicker in the former pit than in the latter.

Since these pit sections were published I have received from Mr. Pogmore an account of the strata sunk through beneath the Seven-feet coal, of which the following is an abstract:—

				FT.	IN.
	Seven-feet coal	-	-	-	5 6
	Fire-clay	-	-	-	3 0
	Blue bind	-	-	-	9 0
	Coal (soft)	-	-	-	1 3
	Fire-clay	-	-	-	4 0
	Coal (soft)	-	-	-	1 6
	Fire-clay	-	-	-	0 3
	Coal (soft)	-	-	-	1 0
	Fire-clay	-	-	-	3 0
	Ironstone in large balls	-	-	-	1 0
	Bind with ironstone	-	-	-	21 7
	Ironstone in balls	-	-	-	0 4
	Blue bind	-	-	-	3 8
	Stone, grey and blue	-	-	-	1 6
	Bind with ironstone	-	-	-	5 0
	Coal (soft)	-	-	-	3 4
	Bind	-	-	-	3 6
	Coal (soft)	-	-	-	2 9
	Fire-clay	-	-	-	3 0
	Coal	-	-	-	0 10
	Bind and ironstone balls	-	-	-	45 11
Bench coal	Coal	-	-	-	5 6
	Fire-clay	-	-	-	2 0
	Coal	-	-	-	11 6
	Fire-clay	-	-	-	4 0
	Black ironstone in balls	-	-	-	0 3
	Fire-clay	-	-	-	4 0
	Black ironstone in balls	-	-	-	0 5
	Shale, with black ironstone in balls from				
	2 to 6 inches thick	-	-	-	9 0
	Black shale	-	-	-	15 0
	Bind	-	-	-	1 6
	Ironstone	-	-	-	0 6
	Bored down in blue bind and ironstone	-	-	-	10 6
Total depth of pit				-	1,101 7

The dip of the strata at Baxterley is about W. 20° S., at an angle of 15°, but this angle is greater where the coals crop to the surface.

The reduced section, No. 2, pl. 1, and the corresponding section No. 1, Sheet 49, on the 6-inch scale, will explain the position in which the Coal-measures lie at Baddesley and Baxterley, and

their extension under the Permian rocks between Baddesley and Kingsbury. It will be seen from this section that the coals extend in a basin-shaped form between Baddesley and Kingsbury under the Permian rocks, gradually rising on the east side of the field in the neighbourhood of Baddesley, from beneath the conformable Permian strata, till they crop out to the surface about half a mile to the east of the pit at Baxterley. About half a mile further east the section crosses the boundary fault of the coal-field, which brings the New Red Sandstone against the lower part of the Coal-measures.

South-east of Baddesley Common the outcrop of the coals can be traced by means of the old workings by the Alders, and through part of Merevale Park, near Square Spinny and Holly Park. At Monk's Park the Seven-feet, Slate, and Rider coals were wrought formerly to a depth of 9 yards, and another coal called the "Smithy" was also partially wrought to the same depth. Ironstone was also raised at the same place, and smelted by charcoal; but what particular bands were used is not stated, though they were probably from under the Seven-feet coal, where they occur in large balls, as shown in Vertical Section No. 6, Sheet 21.

On the south-east side of Monk's Park the coals have been wrought up to the lane which runs between Monk's Park and Spodes Rough; at which point the old workings suddenly cease, which is accounted for by the 19 yards fault, which runs north and south, and shifts the coals further to the south. This fault is a downthrow on the east, and was proved in the old workings of the Four-feet coal at Oldbury. On the east side of this fault the Seven-feet and Bench coals crop to the surface in Spodes Rough, and the Slate, Rider and Bare, and Four-feet coals further to the south-west.

The Seven-feet and Slate coals were formerly worked here to a small extent, and also ironstone. The coals were wrought "level free" to a small depth by means of a day level driven into the side of the hill, from the small brook which runs by Hopwood Coal Wood. The ironstone was worked six yards deep, the line of old pits being almost immediately on the crop of the Seven-feet coal, and the stone was said to be good, but the thickness is not stated. The coals have been wrought to a greater depth than this by the Oldbury engine pit, which was 40 yards deep to the Seven-feet coal. Following the strata further to the south-east, the outcrop of the Four-feet, Rider and Bare, Slate, Seven-feet and Bench coals are well defined by the old workings running through Gin Wood, Ironstone Wood, and Ansley to Nuneaton Common. The Four-feet, Rider, Slate, and Seven-feet coals were formerly wrought to a considerable extent at Ansley. They were first of all worked by means of a day level driven into the hill from the brook near Chapel End, and subsequently by means of an engine pit, the depth of which is not known, on the south side of the turnpike road about half way between Ansley Hall and Chapel End. Another engine pit, nearly opposite the toll-gate, in a field called the Barncroft, was 55 yards deep to the Ell or Slate coal, but no

coals are at present being wrought at Ansley, so that I have not been able to obtain accurately their thickness and that of the intermediate strata. Thomas Walker, an old miner who formerly worked in the mines at Ansley, gave me the following as the number and order of the coals, as far as he could recollect :—

			FT.	IN.
Four-feet coal	-	-	-	-
Intermediate strata	-	-	105	0
Rider coal	-	-	-	-
Intermediate strata	-	-	2	0
Bare coal	-	-	-	-
Intermediate strata	-	-	111	0
Slate coal	-	-	-	-
Intermediate strata	-	-	111	0
Seven-feet coal	-	-	-	-
Intermediate strata	-	-	111	0
Bench coal	-	-	-	-

The Bench coal does not appear to have been wrought so much as the others.

From Ansley the coal-crops continue without interruption in a south-easterly direction to Haunchwood and Blackatree Gate. At Haunchwood the Rider coal goes by a different name, and from its thickness is called the Two-yard coal. The Two-yard, Slate, and Seven-feet coals were formerly wrought at Haunchwood. Since this survey was made a new pit has been opened by Messrs. Nowell and Son, the details of which are given in the Vertical Sections, Sheet No. 21, but only as far as the Two-yard and Bottom coal, which latter represent the Bare coal.* The dip of the coal in Haunchwood colliery is south-east, at an angle of 15°, although at the outcrop the coals are tilted up at a much higher angle, and the Two-yard coal at its basset dips at an angle of 30°. At this point the whole of the coals have been affected by the movement which threw the strata into the form of a synclinal curve and tilted up the Millstone Grit of Hartshill. The old Nuneaton colliery was 168 yards deep to the Slate coal.

From Blackatree Gate the coals bend round and take a rather more southerly direction, passing through Heath End to Griff. At the latter place they are extensively worked on the property of C. N. Newdegate, Esq., M.P.† The engine pit at Griff colliery is

* Since this sheet of Sections was published, I have received from Mr. Nowell the following additional section down to the slate coal :—

				FT.	IN.
Fire-clay	-	-	-	6	0
Binds	-	-	-	33	0
Blue coal	-	-	-	3	8
Rocky binds	-	-	-	13	0
Rock binds	-	-	-	13	0
Black bat	-	-	-	0	7
Binds	-	-	-	1	0
Slate coal, with thin parting	-	-	-	9	6

† The manager of the collieries, Mr. Fletcher, accompanied me over the ground, and gave me every assistance.

144 yards deep to the Seven-foot coal. The direction of the dip in the same collieries is a little south of west, at an angle of 7 inches in a yard. In the southern part at Collycroft the dip is from 10 to 12 inches in a yard, and the depth of the Seven-foot coal there is 98 yards. There are no faults of any importance in the Griff collieries, the largest slip known not exceeding 3 feet.

South of Griff the coals strike nearly due south, cropping east of Bedworth, between the town and Pearce's farm, and from thence they run parallel with the Coventry and Nuneaton Railway to Randles End or Bedworth Hill and the Gin Stables.

By referring to Section No. 4, Plate 1, and Horizontal Section, Sheet 51, the position of the coals where they crop to the surface at Bedworth, and their extension to the west under the Permian strata, will be seen. To the east of the point where the coals crop it will also be seen that the lower part of the Coal-measures, with two intrusive beds of greenstone, rise from beneath the known productive coals, and at Marston Quarry roll over and dip towards the east, at an angle of 15°. We have no evidence, however, how far this easterly dip continues, as the carboniferous rocks are there overlaid unconformably by the Lower Keuper sandstone. There is no doubt that the trap rocks and the shales seen at Marston are a continuation of the same beds seen in the railway cutting at Chilvers Coton near Nuneaton, but where the section crosses we have no detailed information of the strata between these beds and the Bench coal.

As already stated, the coals in Hawkesbury colliery come together and form nearly one thick seam; and a detailed section of one of the pits is given in the Vertical Sections, Sheet 21, which shows the coals that are at present wrought there. Clay ironstone is also extensively worked at Bedworth, Hawksbury, and Wykin, not in one continuous bed, but in balls or nodules of great size. This ironstone lies almost immediately beneath the Slate coal, as shown in the pit sections of Bedworth, Hawkesbury, and Wykin.

Since these sections were published I have received from Mr. Harden an account of the strata sunk through at a new pit near Hawksbury Basin, (which goes much deeper than any in the neighbourhood,) of which the following is an abstract, from the Seven-foot coal downwards:—

				FT. IN.
1. "Seven-foot" coal	-	-	-	4 10
2. Fire-clay	-	-	-	11 6
3. Black scud	-	-	-	3 0
4. Fire-clay	-	-	-	8 9
5. Coal	-	-	-	1 6
6. Sandstone (with much water)	-	-	-	20 8
7. Sandstone	-	-	-	7 0
8. Fire-clay	-	-	-	8 0
9. Black scud	-	-	-	2 3
10. Coal	-	-	-	0 9

B 2

					FT.	IN.
11.	Fire-clay	-	-	-	4	6
12.	Ironstone ball	-	-	-	1	0
13.	Binds	-	-	-	19	9
14.	Coal	-	-	-	2	0
15.	Fire-clay, with coal streaks	-	-	-	9	0
16.	Coal	-	-	-	3	0
17.	Fire-clay	-	-	-	2	0
18.	Coal and Bat	-	-	-	2	0
19.	Fire-clay	-	-	-	4	0
20.	Black ironstone balls	-	-	-	2	0
21.	Black bat	-	-	-	1	0
22.	Coal	-	-	-	1	0
23.	Fire-clay	-	-	-	6	0
24.	Binds	-	-	-	5	0
25.	Fire-clay	-	-	-	1	10
26.	Coal	-	-	-	2	5
27.	Bind and ironstone balls	-	-	-	10	6
28.	Grey rock and bind	-	-	-	3	7
29.	Ironstone band	-	-	-	0	4
30.	Brown rock	-	-	-	2	8
31.	Black loose scud	-	-	-	1	2
32.	Coal	-	-	-	1	4
33.	Bind and ironstone bands	-	-	-	12	4
34.	Ironstone	-	-	-	2	0
35.	Bind and ironstone bands	-	-	-	14	3
36.	Black shale rock	-	-	-	0	6
37.	White rock binds	-	-	-	1	6
38.	Black binds	-	-	-	42	0
	Alternations of hard black bat and					
	granite-like rock in boulders	-	-	-	172	9

In this section Nos. 14, 16, and 18 would probably represent the Bench coal. No. 20 is a new ironstone, not having been wrought before; it is a good black ironstone, yielding 45 per cent., and producing 9 cwt. per yard.

In the last part of the section it will be seen that there is 172 feet of "Hard black bat and granite-like rock in boulders." This is as it was described to me by Mr. Harden, as he did not know what else to call it. It is certainly not granite, but not having seen the rock in situ I am unable to say precisely whether it is trap or an altered sedimentary rock, and I know nothing in the district like it. From a hand specimen which I brought away, it appears to be very hard and compact, containing a small quantity of carbonate of lime, and crystals of glassy felspar and iron pyrites. The black shale or bat in contact with it appeared to be altered by heat.

South of the Gin stables the Coal-measures are overlapped unconformably by the Lower Keuper sandstone, so that after this point the coals do not crop out to the surface, but against the base of the horizontal beds of the Lower Keuper sandstone, as shown in the accompanying woodcut.

Fig. 2.



This unconformity has been proved in all the collieries south of Hawksbury. A section is given of one of the old Wykin collieries, in Vertical Sections No. 5, Sheet 21, in which the position of the horizontal beds of the Lower Keuper sandstone on the Coal-measures is shown. It will be seen from this, that before coming to the Coal-measures they passed through 85 feet of the Lower Keuper sandstone, the beds of which were horizontal. There are also some beds of red sandstone and marl dipping at the same angle as the Coal-measures, and this may probably be part of the Permian strata, also overlapped by the New Red Sandstone, but of this I am not certain.

During the latter part of the survey of this coal-field, a new colliery was commenced by the Exhall Colliery Company, but its position is not marked on the map. It is in the corner of the angle formed by Little Sydnal Lane and the turnpike road between Exhall Green and Bedworth. An arrow showing the dip of the strata will be seen at this spot on the map, marking nearly the position of the new shaft. The pit was not finished when I was in the neighbourhood, and I was told afterwards that further progress had been stopped. A section of the strata passed through is given in the Vertical Section No. 14, Sheet 21, as far I believe as the sinking was carried forward, from which it will be seen that 95 feet of Drift was first passed, and after that 150 feet of Permian rocks, before coming to the Coal-measures. A bed of light blue limestone was reached after passing through 95 feet of Coal-measures, but whether this represents the limestone bed containing the *Spirorbis Carbonarius* I am unable to say, for the specimens which were shown me at the pit-mouth did not resemble the limestone wrought at Griff. The stone was not nearly so good, and was too impure for any use, neither did it contain the *Spirorbis*, but its position in the section is about the same, which makes me think it may represent this limestone. One thin bed of coal was also passed through lower down, although it is impossible to identify it with any particular bed in the other sections in the neighbourhood. I think it very likely that they have not yet reached any of the strata which are sunk through in the collieries of Wykin and Hawksbury, which are considerably to the east of this new colliery, and consequently are situated on lower beds. The dip of the rocks at the Exhall colliery is west at an angle of 15° , the Permian beds having the same dip as the Coal-

measures. In sinking through the Permian strata, which consist of alternations of sandstone and marl, (the sandstone sometimes a calcareous breccia,) enormous quantities of water were met with. This was also the case in the Coal-measures, and had the sinking been continued it would probably have drained the pits on the rise of the beds further east.

South of Hawksbury the outcrops of the coals have been proved as far south as Wyken House, about three miles north-east of Coventry. I was refused by the lessee of the Craven colliery any section of the Wykin engine pit, which is said to be 234 yards deep to the Slate coal. The thickness of the Lower Keuper sandstone is here 36 feet, consisting of white sandstone and red marl lying horizontally on the Coal-measures; and the coals and ironstone both at Hawksbury and Wykin have been wrought up to where they crop against the overlying horizontal New Red Sandstone, the base of which is generally conglomerate, which the miners in the district call a "gravel wall." When describing to me the position of the coals they always used this expression, meaning that the beds of coal crop up against these horizontal measures.

The Craven colliery is furthest south of any colliery in the district, being near Wykin House, about 3 miles north-east of Coventry, in sheet 53 north-west. The depth of the Craven pit to the Slate coal is 50 yards, and the dip of the coal where it crops against the Lower Keuper sandstone is about 20 inches in a yard; this dip getting considerably less in following the dip of the coal to the west. The outcrop of the Slate coal is about 10 yards east of the shaft at Craven colliery. Where the coal crops are overlapped I have dotted in the lines, showing where they crop against the base of the New Red Sandstone, having been traced as far south as Wykin 3 miles north-west of Coventry. The dip at Craven colliery is west, but at the last place where it is known the strike was turning more to the south-west towards Coventry. It is impossible to say how far the coal basin extends south under the Permian rocks and New Red Sandstone, and this can only be proved by actual boring, but the probability is that the coals do exist under Coventry, although at a very considerable depth.

It will be seen by the map 62 S.E. that the Coal-measures cease at the surface near Kingsbury, and the only place where they are exposed on the western rise of the basin is at Arley Wood, about 5 miles west of Bedworth, but this gives us no clue as to the actual extent of the basin to the south.

I shall now describe the position and outcrop of the coals on the west side of the basin. This side of the coal-field, like the east side, is bounded by a north and south fault, which brings the New Red Sandstone against the Coal-measures, and the two faults meet each other at the northern extremity of the coal-field at Spring Coppice, near Shuttington, where they bring the New Red Sandstone against the upper part of the Coal-measures.

The village of Shuttington lies very nearly in the centre of the trough of the Coal-measures, consequently the workable coal-seams there would be at a considerable depth. Formerly there was a thin coal worked immediately to the west of Shuttington, but the workings are so old I could get no information what coal it was. Most probably it was one of the thin upper coals which are sunk through at Glascote Colliery.

The horizontal section No. 2, Sheet 49, explains the position of the workable coal-seams at this part of the coal-field, and also the probable way in which the Coal-measures are cut off by the fault which brings the New Red Sandstone against them. This section runs in a north-east and south-west direction across the north end of the coal-field, and is taken as near as possible along the synclinal line of the coal basin, which accounts for the coals appearing in it in a horizontal position. There are no pits immediately on the line in which the section is taken, but from knowing the depth and dip of the coals on each side of the coal-field, the probable depth of the same beds in the line of section has been estimated. If this be correct the depth of the Seven-feet coal at Shuttington and at the north end of the coal-field will be between 650 and 700 feet.

Proceeding south, the first place where the coals are wrought on the west side of the coal-field is at Glascote, near Tamworth. This colliery, belonging to Messrs. Gibbs and Canning, is not marked on the Ordnance map, but it is close to Glascote Coppice, by the side of the Tamworth and Polesworth turnpike road, about a mile and a quarter from Tamworth. The pit is sunk to the Bench coal, and the depth of the pit and a section of the strata passed through is given in Vertical Section, No. 1, Sheet 21.* There are also two more collieries, sections of which are given in detail in the same sheet, viz., the Kettlebrook and Wilnecote Collieries;† and these three are the only collieries now at work on the west side of the basin. It will be seen by comparing the sections that they agree very well with regard to the principal coals, although in some of the smaller ones and intermediate measures there are discrepancies. This is easily accounted for by making allowance for the thinning out of some beds, and also the different descriptions given by the persons who took an account of the sections when the pits were sunk.

The section, No. 1, Plate 1, and Horizontal Section, Sheet 48, will explain the position in which the principal coals at Glascote and Kettlebrook collieries occur, showing their connexion with the same seams which crop out on the east side of the coal-field at Polesworth, and the reason why they do not crop to the surface west of Glascote and Kettlebrook. It will be seen from this section that the coals between Glascote Colliery and Polesworth lie in a regular trough, and it is well known that the coals which are

* This section was given me by Messrs. Gibbs and Canning, who also gave every other information I required.

† Communicated by Mr. Dumolo and Mr. H. Johnson.

worked at Glascote are the same as those at Polesworth, dipping towards each other. Immediately to the west of Glascote Colliery the Seven-feet coal, which is 440 feet deep there, has been wrought up to a fault, which throws all the coals down to the west 26 yards, and runs nearly parallel to the boundary fault of the coal-field. This fault has also been proved at Kettlebrook; and further to the west another fault has been met with, running nearly parallel to the last, but having a downthrow on the east, the coals lying in a trough between them. This last fault was proved at Kettlebrook to throw the coals down 18 yards to the east, and beyond this the coals continue without interruption till they are cut off and thrown down to the west by the boundary fault of the coal-field, which at this point brings the Lower Keuper sandstone against the coal-measures. This great boundary fault was proved in the old working of the Park Colliery a little to the south of Glascote, where the coal was wrought up to the "Red Rock" fault. From the above description it will be seen that between Shuttington, Glascote, and Park Colliery, near Two Gates, the New Red Sandstone is brought by the boundary fault against the upper part of the Coal-measures, the workable coals not cropping out to the surface, but being brought against the New Red Sandstone by the fault.

At Two Gates, near Fazeley, on the Watling Street, we find the coals rising to the surface, although the evidence as to the precise outcrop of each coal is rather obscure, and consequently they have only been indicated by dotted lines on the map. The coals at Two Gates, near the outcrop, are apparently very much troubled by the meeting of faults, evidence of which was seen in lowering the Watling Street, between Two Gates and Fazeley. The faults which pass through Glascote and Kettlebrook both point towards this spot, which may account for the coals being so much disturbed. The Seven-feet coal is said to crop out about 50 yards to the west of Two Gates in the Watling Street. From the small amount of evidence I was able to obtain of the old Park Collieries, there were apparently two coals wrought, viz., the Seven-feet and Bench coals, and though I could not learn the exact depth of the pits, I was told they were more than 100 yards, and the coals had a dip towards the north-west. A section of the rocks seen in a clay pit on the east side of the road, between Two Gates and Tamworth, just opposite the Park Colliery, has a dip to the north-west of 10° . The Bench coal was also wrought near Two Gates, where the pit was sunk immediately under the outcrop of the Seven-feet coal, and was 42 yards deep.

South of Two Gates the outcrop of the five coals can be distinctly traced by means of numerous old pit heaps, running nearly parallel with the Midland Railway, where the coals had been formerly wrought near their outcrop. The coals here all dip a little to the south of east at a small angle, and the Midland Railway in the cutting at the Wilnecote Railway Station is said to be in the "waste" of the old Seven-feet coal workings, the depth of the old pits to that coal being about 14 yards. In a range of old pits close to the public road, a mile and a half south of Two Gates, the

depth to the Seven-feet coal was 15 yards. The old Wilnecote Colliery was situated close to the Midland Railway, three-quarters of a mile south of the Wilnecote Station, the engine-pit of which was 100 yards deep to the Seven-feet coal; the level from this pit ran in a direction of Wilnecote Church, although the coal was not wrought beyond the lane which leads from the west end of Wilnecote to the railway near Dosthill, and its dip was about 20° south of east at an angle of 8° . At Dosthill the whole of the coals are tilted up and inclined at a high angle, in the neighbourhood of the Greenstone which has been forced up in the line of the boundary fault of the coal-field here, the lowest coal and the other rocks associated with it being much altered where in contact with the trap rock.

From Dosthill the coals strike almost in a straight line directly south, caused by the high angle at which they are inclined, and at the point where they cross the Midland Railway there is a good section of all the coals and the strata associated with them exposed in a deep cutting, the whole dipping nearly due east at an angle of from 75° to 80° . The high angle at which the coals are inclined here does not continue in the direction of the dip for any great distance, the strata becoming gradually flatter going eastward. The way in which the coals at this point are tilted up will be seen by referring to the Section No. 3, Plate 1, and the Horizontal Sections No. 2, Sheet 49. Some of the coals were formerly worked on the east side of the railway, at the brickworks near Slateley, but the information I was able to obtain was very scanty. Close to the west of the brickworks there was an engine-pit 120 yards deep sunk nearly on the almost perpendicular dip of one of the coals, but which of them I could not ascertain. To the south of the brickworks the coals can be traced to Thistlewood Brook, where they are suddenly cut off by the boundary fault, and thrown down on the west, the New red marl being brought against the Coal-measures. The amount of throw of this fault cannot with accuracy be ascertained, but that it is large seems certain from the fact of the upper division of the New Red Sandstone being brought against the upper part of the Coal-measures.

The Coal-measures continue at the surface for about 2 miles further south, having the same easterly dip, although not at such a high angle, till they end in a point at Flanders Hall, formed by the boundary fault of the coal-field, bringing the New Red Marl against the Permian strata.

By referring to the Section No. 2, Plate 1, and the Horizontal Sections No. 2, Sheet 49, the manner in which the New Red Marl is brought against the Coal-measures, and the probable depth and position of the coals on the east side of the fault at Kingsbury is shown. This section, which is taken across the Warwickshire coal-field, between Kingsbury and Baxterley, near Atherstone, shows the probable depth at which the coals will be found under the Permian rocks in the centre of the coal basin.

The thin limestone which lies in the upper part of the Coal-measures is seen to crop on both sides of the basin, viz., at Sybil

Hill, near Kingsbury, on the west, and at Baxterley Common on the east. The thickness of the strata between this bed of limestone and the workable seams of coal has been proved at Baxterley (see Vertical Section, Sheet 21), and there is every reason to suppose that the same coals will be found about the same depth below the limestone on the west near Kingsbury.

About 6 miles to the south-east of Kingsbury, at Arley, there is a small patch of Coal-measure seen lying in the middle of the Permian rocks. It is about a mile in length and half a mile broad, and although much obscured by drift, it is known to be the upper part of the Coal-measures from the presence of the limestone which was formerly wrought at Arley Wood, this being the same bed of limestone which occurs in the upper part of the Coal-measures on the east crop of the coal-field, and which was formerly wrought at Ansley. The connexion between this outlier of Coal-measures and the main beds of the coal-field at Ansley will be understood by referring to Section No. 5, Plate 1, and Horizontal Section No. 2, Sheet 51, in which will also be seen the probable depth at which workable beds of coal may be found at Arley Wood and under the Permian rocks between Arley Wood and Ansley.

The appearance of the Coal-measures at Arley is probably due to the fault which forms their western boundary in combination with the general denudation of the Permian strata. This fault runs nearly north and south, and is an upthrow on the east, and I think it probable that it is a continuation of the 19 yards fault which was proved at Oldbury. The connexion of the Coal-measures at Arley with the last point where they are seen at Flanders Hall on the western crop cannot be seen on account of the Permian rocks overlapping the Coal-measures; but there can be no doubt that the Coal-measures are continuous underneath the Permian rocks between these two places, although at what depth there is no evidence at present to enable me to tell. I shall have occasion, when describing the line of outcrop of the limestone, to allude to the probability of its having been wrought formerly at Whitacre Hall, and if it is true that the limestone was wrought there, this gives some clue as to the outcrop of the upper part of the Coal-measures beneath the Permian rocks between Flanders Hall and Arley.

Limestone with Spirorbis Carbonarius.

In the higher part of the Coal-measures of this coal-field, as already stated, there is a thin bed of limestone, which generally occupies a position about 50 feet below the lowest bed of the Permian rocks. It is generally from two feet to three feet thick, and contains the small serpula *Spirorbis carbonarius*, and is locally known as and erroneously called the "freshwater limestone." It is seldom seen in situ, although from the numerous old workings the position of its outcrop is well defined.

By referring to the Geological maps, 62 south-east and 63 south-west, the crop of the limestone will be seen following the boundary of the Coal-measures and Permian strata, maintaining an average

distance of rather less than a quarter of a mile from the junction of those formations. The first place where it is seen on the west side of the coal-field is at Sybil Hill, near Kingsbury, and it probably continues further south than this, as indicated on the map, although it does not appear to have been wrought, till cut off by the boundary fault of the Coal-measures. North of Sybil Hill, and east of Lodge Barn and New House, the limestone was formerly worked in open quarries, and although they have been long abandoned, the line of old workings can be traced along the west side of Kingsbury Wood and Edge Hill Wood. In a clay pit by the side of the lane between Edge Hill Wood and Wheatly the limestone was found a few feet below the surface two feet thick. Further north it was formerly wrought at the Dumbles, and turning round south of Freasly the outcrop may be traced by the old quarries near Overhouse, and from thence through Biddles Wood to Ensor, Breedon Rough, Baxterley Park, and Baxterley Common to Baker's Gorse. At the Stratford pit, on Baxterley Common (see Vertical Section No. 9, Sheet 21), they passed through the limestone, and it was found to be two feet six inches thick. The position of the limestone here, and its extension under the Permian strata to the west, till it crops again at Sybil Hill near Kingsbury, will be seen by referring to Section No. 2, pl. 1, or to the Horizontal Section, Sheet 48.

Between Baker's Gorse and the Nineteen-yards fault at Monks' Park there are no indications of the limestone having been wrought, and its precise outcrop is uncertain; but there can be no doubt that it would be found occupying the same position here as at other places, following the boundary of the Permian rocks. On the west side of this fault, the first place where it appears to have been wrought is at Lady Wood, showing that it has been shifted by the fault considerably to the south, in the same manner as the coal seams previously described, and from whence the line of old workings can be traced at intervals passing just west of Ansley Hall and through Ansley Park, Galley Common, a quarter of a mile south of Nuneaton Common.

Between Whiteford and Stockingford the precise outcrop is uncertain, consequently the line has here been dotted to show its probable position; and this is most likely very near the truth, for immediately south of this point there are indications of its having been formerly wrought at the surface at Swan Lane and a little to the east of Coton Lawn, the outcrop being just about the same distance from the Permian boundary as at Ansley. Further south it is at present being worked in pits near the Bracknells, immediately west of the Griff Colliery, and the old crop workings can be traced through Bond's Rough southwards towards Bedworth and Collycroft, where it is at present being worked in pits. It was also formerly wrought at Springfield House, a little to the south of Bedworth. There are no indications of this limestone having been wrought either in pits or in surface workings south of this point, and the precise outcrop of the bed is not accurately determined, although there can be little doubt that it will be found in the same

position as in the other places previously described, and not much out of the line indicated on the map. We have good reason to suppose this to be the case from the fact of a bed of limestone having been found in sinking the shaft at the Exhall Colliery; (See Vertical Sections, Sheet 21, Sec. 14), for though it is not quite certain whether this is the same bed which is worked near Bedworth, the limestone found in the shaft here not being so pure, it may possibly represent it. It will be seen by referring to the pit section that it is much thicker here than at the other places where it has been proved, although it occupies much about the same position in the Coal-measure strata as at the Stratford Colliery at Baddesley. From the specimens which were shown me at the pit it had certainly changed its character considerably if it was the same bed, and, as already stated, no traces of the small *Spirorbis carbonarius* were detected in any of the fragments.

South of this point (if it continue) it will be found to be overlaid unconformably by the Lower Keuper Sandstone, and consequently will not crop to the surface. The Wykin and Hawksbury Collieries are considerably to the rise of where the line of outcrop should be, and the shafts there do not therefore pass through the limestone, but it is most probable that as the pits are sunk more to the west it will be found in its ordinary position in the Coal-measures beneath the Lower Keuper Sandstone.

This limestone, as already stated, also occurs in the small inlier of Coal-measures at Arley, about half way between Nuneaton and Coleshill, on the western rise of the strata. It was formerly wrought at the surface in Arley Wood, and has a dip to the east of 6° . That it is the same bed of limestone cannot be doubted, from its having precisely the same thickness, viz., from two to three feet, as on the opposite side of the Coal-measure basin between Bedworth and Ansley, and also because it contains the same fossil, *Spirorbis carbonarius*, besides having the same relative position in the Coal-measure strata that it has at Bedworth and along the whole eastern crop of the coal-field, being about 150 feet below the lowest bed of the Permian rocks.

The termination of the limestone at Arley Wood on the north and south is very obscure from the thickness of Drift gravel which covers the ground, but it appears to be cut off by a large fault having a downthrow on the west, which would shift it considerably to the south-west towards Over Whitacre. This fault is most probably a continuation of the Nineteen-yards fault, which was proved on the opposite side of the coal-field near Ansley, but at Arley Wood the amount of the "throw" is uncertain.

There can be little doubt that the limestone exists under the Permian rocks between Arley Wood and Sybil Hill near Kingsbury, although it is impossible to point out its precise position beneath that formation. There are, however, some indications of its having been wrought at Whitacre Hall, about half way between Arley and Kingsbury. It was certainly burnt there, for the old kilns remain, and fragments of the limestone partially burnt are seen lying about the fields, but whether it was brought from

Arley Wood, or Kingsbury Wood, or quarried on the spot, could not be ascertained, the works having been long abandoned. It is quite possible that the limestone may have been quarried here, exposed by the denudation of the Permian rocks.

The occurrence of the *Spirorbis* limestone at Arley proving the extension of that bed under the Permian rocks which occupy the centre of the basin is very important, and enables us to estimate with tolerable accuracy the depth at which the coal seams which are wrought on the east crop of coal-field between Ansley and Baddesley would be found on this side of the basin, showing that it is probable they are here at workable depths under the Permian rocks. This will be seen by referring to Sections Nos. 2 and 5, pl. 1, and to the Horizontal Sections, Sheets 49 and 51, which show the connexion of the limestone at Kingsbury and Arley Wood with the same bed which crops on the east side of the coal-field under the overlying Permian strata. The limestone is known to belong to the Coal-measures, and is perfectly conformable over the whole Coal-field on the productive Coal-measures which underlie it, and there is every reason to believe that the intermediate measures between it and the coal seams are about the same thickness on each side of the basin.

There is one more place where this same bed of limestone has been found, and although very little is known as to how it occurs, it may be better to give the evidence as it exists. The locality referred to is immediately to the west of the Glascote Colliery near Tamworth, close to the great boundary fault of the coal-field. Messrs. Gibbs and Canning, of Glascote Colliery, had a well sunk at some new cottages by the side of the turnpike road between Tamworth and Glascote, about a mile from Tamworth. The well was commenced in the Lower Keuper Sandstone, immediately west of the boundary fault of the coal-field, and at the depth of thirty yards fragments of the limestone in true Coal-measures were found. It was proved to be the same limestone by the Rev. P. B. Brodie of Rowington, who detected *Spirorbis carbonarius* in it. The fragments which were brought up appeared to be very much shattered and broken, probably caused by being so close to the boundary fault. There was no regular bed of it discovered, and it is possible that these fragments may have come out of the line of fault, but in any case the occurrence of the limestone here is important, and may indicate an extension of the Coal-measures to the west under Tamworth, but at a very considerable depth.

CHAPTER III.

PERMIAN ROCKS.

THE Permian rocks occupy a very considerable tract of country in this district, and are of very great thickness, resting directly on the Coal-measures, and as a general rule being conformable to them. They principally occupy the country commencing on the north near Baddesley Ensor, and terminate on the south about two miles north of Leamington and Warwick, where they are overlapped by the Lower Keuper Sandstone. The thickness of these rocks altogether cannot be less than 2,000 feet.

Over the whole of this district, from the lowest beds to the highest that are exposed, they present an appearance of great uniformity, and on the whole bear a striking resemblance to the rocks below the great brecciated conglomerate that partly surround the South Staffordshire coal-field, consisting of alternations of pale red, brown, and purple sandstones, and red marl, with beds of calcareous breccia and conglomerate. These latter are generally in the lower part of the formation, and sometimes exist in continuous beds, but more commonly in lenticular masses, not uniform in thickness over any great distance, but thinning out in every direction.

These breccias and conglomerates are sometimes so calcareous as to form an impure limestone. They all contain pebbles of various kinds from older rocks, and in one of the beds near Exhall there were found pebbles consisting of fragments of Silurian sandstone much like the upper Llandovery sandstone, containing *Atrypa hemispherica*; also fragments of Carboniferous limestone, with *Spirifer attenuatus* and corals. The nearest carboniferous limestone is twenty-one miles distant from this district, at the north end of Charnwood Forest, but the pebbles may possibly have been derived from other masses concealed beneath the New Red Sandstone. The calcareous breccia can be well seen on the road side between Fillongley and Over Whitacre, where it has been extensively quarried, and was formerly burnt for lime, and the same sort of rock has also been quarried near Whitacre Hall, Rush Flanders, and Tibb Hall, about five miles north-east of Coleshill, and at the village of Hurley near Baxterley. The breccia at all these places lies in about the same horizon in the Permian strata, but it has been found impossible to connect them and lay them down on the map in a distinct bed.

In the north and central part of the coal-field the lower Permian beds lie in the centre of the trough of Coal-measures, and their boundary follows the general contour of the coal-field along the eastern crop between Baddesley and Hawksbury. In Horizontal Sections, Nos. 1 and 2, Sheets 49 and 51, the position of the Permian strata, and their general conformability to the underlying Coal-measures in the north and central part of this coal-field, will be seen. This, however, is not universal over the whole district,

for we find in the Wykin Colliery, Vertical Section No. 4, Sheet 21, that the Permian rocks rest upon lower beds of the Coal-measures than in the north part of the field, which is proved by the fact of the bed of limestone not being found immediately after passing through the Permian strata.

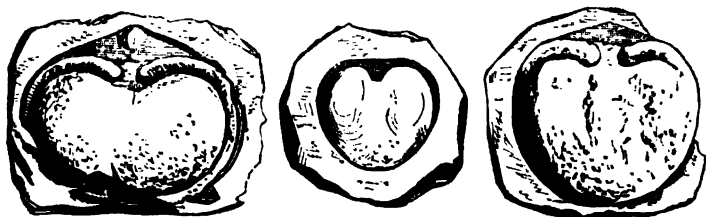
The general dip of the Permian rocks between Exhall and Kenilworth is south-west, and we gradually get into higher beds as we proceed in that direction. About four miles west of Exhall there is a very distinct bed of conglomerate, which forms a kind of horizon about the middle of the Permian strata, and it can be traced along the surface for eight or ten miles. This bed is best seen at Corley, about six miles north-west of Coventry, where it forms an abrupt escarpment to the north-east, the beds dipping to the south-west. The position which it occupies will be seen in Section 4, pl. 1, and Horizontal Section, Sheet 51, which crosses at Corley. It is composed principally of rounded pebbles of quartz, Carboniferous limestone, and chert. Except at Corley, the precise boundary of this conglomerate is not easily defined, but it strikes south-east towards Coventry, and is well exposed in the Coventry and Nuncaton Railway, under the bridge over which the road between Coventry and Corley passes. It is also seen in Whitley Common, south-east of Coventry, beyond which it is lost under the Lower Keuper Sandstone, which overlaps it at this point.

Above this conglomerate the Permian beds become more marly, with fewer beds of calcareous breccia and conglomerate. These are well exposed between Coventry, Kenilworth and Warwick, in the Leamington and Coventry Railway, and their marly character was further proved near Warwick, where a boring was made, to supply the town with water, through 700 feet of rock, consisting mostly of marl and thin beds of sandstone.

The rocks which have just been described were formerly supposed to be New Red Sandstone. During the progress of the survey of this coal-field, Professor Ramsay first doubted whether they really belonged to the Triassic period; for they so perfectly resembled, both in colour and lithological character, those surrounding the south part of the South Staffordshire coal-field, which had been decided as belonging to the Permian formation by Professor Ramsay and Mr. Jukes, that it was found impossible to doubt their identity, especially as both directly overlie the Coal-measures, and in both districts they are unconformably overlaid by the New Red Sandstone.

It was after having decided these rocks to be Permian that Professor Ramsay was further confirmed in his opinion by finding fragments of *Lepidodendron* and *Calamites* in a quarry near Exhall. This was followed by Mr. Richard Gibbs, the fossil collector of the Geological Survey, finding a few casts of a shell (Fig. 3), considered by Mr. Salter to be of Permian type, and more allied to *Stropholonia* than to any other genus.

Fig. 3.



Fossil allied to *Stropholonia*?—"Internal casts in coarse sandstone."—Permian Sandstone, Exhall, Warwickshire.

"The silicified trees found near Allesley and Meriden, and apparently several species of *Caulerpites* and *Breca*, now in the Warwick Museum,* belong also to the same rocks (formerly supposed Bunter species); and in addition to this, it is interesting to know that the beds near Kenilworth, in which the *Labyrinthodon Bucklandi* was found by Dr. Lloyd, belong to the same series. This reptile, previously considered of Bunter date, must therefore be transferred to the Permian period." (See Ramsay, Quart. Jour. Geol. Soc., vol. xi., p. 198.)†

Another reason why these rocks are classed as Permian is, that they are more nearly conformable to the Coal-measures underlying them than to that part of the New Red Sandstone which rests decidedly unconformably upon the Permian strata—an unconformity which was proved in the Wykin Colliery, near Coventry, where the Lower Keuper Sandstone was found lying horizontally (all the Bunter beds being absent), whereas the underlying Permian and Coal-measure strata are tilted up at a considerable angle.

In the north part of the coal-field there is a small outlier of Permian sandstone, about the centre of the coal trough between Polesworth and Glascote. This outlier is about three miles distant from the main body of the Permian rocks which have just been described, and rests upon lower beds of the Coal-measures. That this is the case is proved by the absence of the beds of limestone, which also shows that the Permian formation is here really unconformable to the Coal-measures, and further, that the conformity further south is probably accidental, like that at the south part of the South Staffordshire coal-field, whereas further north there is an entire unconformity between them. The sandstone of this outlier is mostly calcareous, and may be seen in the lane just north of Callas. The south side is bounded by an east and west fault, being a downthrow on the north, which may account partly for its preservation.

In the north-east part of the coal-field near Polesworth we find the Permian strata rising from beneath the conglomerate of the

* *Caulerpites oblonga*, *C. triangularis*, *C. biangularis*, *Breca entassoides*. No precise locality is given for these specimens.

† See p. 52.

Bunter beds on the east, and brought against the upper part of the Coal-measures on the west by the boundary fault of the coal-field. They may be seen in the road between Polesworth and Waverton immediately east of the bridge over the Trent Valley Railway. The road at this point has been lowered, and in the section exposed in the cutting, the junction of the Permian strata and the conglomerate may be seen. The Permian beds consist of calcareous red conglomerate near its junction with the New Red Sandstone, and immediately below these calcareous strata there are beds of breccia containing angular fragments of quartz rock and purple sandstone, several of them many inches in diameter. The calcareous conglomerate above also contains some pebbles of quartz, purple sandstone, and crystalline limestone. The same beds are also seen immediately south of this near the Railway Viaduct over the river Anker, dipping under the Bunter conglomerate at an angle of 15° . A quarry in the same beds can also be seen by the side of the brook between Bury Hill and Bramscote Hall, the strata dipping under the conglomerate at much the same angle.

From the brecciated character of the Permian strata in these sections, they probably belong to the lower part of the formation, and the productive Coal-measures might be found at no great depth beneath them, although we have no positive evidence as to their exact depth; for on account of the Permian beds being faulted against the Coal-measures, we do not see the lowest strata, and consequently cannot tell the precise thickness of the Permian rocks at this point.

Between the Warwickshire and South Staffordshire coal-fields we find several patches of Permian strata, partly brought up by faults, and exposed by the denudation of the New Red Sandstone. One of these patches is exposed near the village of Hints, about four miles south-west of Tamworth, and is bounded on two sides by faults, both of which run more or less north and south, and meet in an angle near Canwell Hall. Being downcasts on opposite sides, these faults have probably caused in a great measure the Permian beds to be exposed here. The north part of this Permian patch forms a natural boundary with the conglomerate of the Bunter beds; and it contains one or two thin calcareous bands, which have been marked in the map in blue.

Immediately to the west of this the Permian rocks are again exposed in a long narrow strip, probably bounded on all sides by faults. Very few sections are exposed, but in the places where it is seen *in situ*, it consists of marl, with thin beds of purple sandstone interstratified, and very much resembles the highest Permian beds in the neighbourhood of Warwick and Leamington.

The occurrence of these Permian strata in the centre of the New Red Sandstone between the two coal-fields, renders it extremely probable that a great thickness of these rocks underlies the New Red Sandstone, although we have no data by which to form a correct estimate of their thickness.

The Permian rocks are again exposed about a mile north of Aldridge at Stonall Gorse, dipping to the south-east at an angle of 45° , under the conglomerate beds of the New red sandstone, which lie unconformably upon them. The quarries where they are seen are shown on the map by the arrows, which denote the direction of the dip of the strata.

CHAPTER IV.

THE TRIAS, OR NEW RED SANDSTONE ; AND LIAS.

THE New Red Sandstone consists in this district of the following subdivisions, given in descending order:—

- | | |
|---|-----------|
| A. Red and mottled marls and upper Keuper sandstone - - - - - | } Keuper. |
| B. Lower Keuper sandstone or water-stones | |
| C. Upper red and mottled sandstone - - - | } Bunter. |
| D. Conglomerate, or pebble beds - - - | |

It will be observed that the Lower red and mottled sandstone, which is almost invariably present beneath the conglomerate when the New Red Sandstone series is complete in all its divisions (as at Kidderminster, Bridgenorth, and the west side of the South Staffordshire coal-field) is here absent. The whole of the remaining subdivisions given above are not constant over all the district to which this memoir refers, and we shall find that the Bunter division thins away rapidly from the north-west to the south-east, till, in the neighbourhood of Coventry and Warwick, and generally on the east side of the Warwickshire coal-field, it disappears entirely, and the Keuper sandstones and marls rest directly on the Permian rocks and the Coal-measures.

D. Conglomerate or Pebble Beds.—This is the lowest subdivision of the New Red Sandstone as developed in this district. It consists of pebbles of quartz, carboniferous limestone, and chert, millstone grit, and other rocks, all being very much rounded and waterworn. Sometimes they attain a size of nine inches in diameter, being generally cemented together in a sandy matrix. Where in contact with each other they are frequently indented at the points of contact, and this often forms a very good sign by which to distinguish the conglomerate of the New Red Sandstone from the ordinary Drift, which is chiefly composed of the same pebbles re-arranged. The Drift also has not the compact and stratified appearance which the conglomerate has, the indentations on the pebbles having been generally removed by subsequent attrition.

The conglomerate is principally developed in this district immediately to the north of Birmingham, and forms the high ground at Barr Beacon, Sutton Park, and Aldridge; and further north it

appears in the neighbourhood of Lichfield, and at Hints, and Hopwas Wood, near Tamworth. At Barr Beacon and Sutton Park we are enabled to estimate with tolerable accuracy the thickness which it attains, for here we get nearly a complete section of the conglomerate, as shown in the Horizontal Section No. 1, Sheet 49, in which the position of the subdivisions of the New Red Sandstone between the South Staffordshire and Warwickshire coal-fields are shown. The thickness of the conglomerate, according to this section, is about 450 feet, and it continues about the same thickness further north near Lichfield.

From Barr Beacon the conglomerate continues northwards through Aldridge, in a continuous escarpment, as far as Lazy Hill, the western boundary being brought against the Coal-measures by the eastern boundary fault of the South Staffordshire coal-field. Further to the north, at Stonall Gorse, it lies unconformably on the Permian rocks, and the dip lies more to the north-east, as seen in a gravel pit by the side of the road between Upper Stonall and Shire Oak Farm, the general strike of the beds of the New Red Sandstone being towards the west, till they are brought against the Coal-measures by the boundary fault.

About mid-way between the northern part of the South Staffordshire coal-field, and the Warwickshire field at Tamworth, the conglomerate occupies a considerable area, and is much broken by faults. By referring to the Horizontal Section No. 1, Sheet 48, the position of the conglomerate with reference to the other divisions of the New Red Sandstone and the Permian rocks will be seen, and also the different levels to which it has been thrown by the numerous faults which intersect this part of the district. About two miles west of Tamworth it forms a high ridge between Hints and Tamhorn Park. The line of fault which runs along the base of this ridge throws the Keuper Marls to a considerably lower level than the conglomerate. Numerous sections may be seen, more especially at Hints Hill, where the Watling Street has been cut through it, and also in a large gravel pit near Hints Church, and in several quarries in Hopwas Hayes Wood.

Near Lichfield the conglomerate may be well seen at Femley Pits, about a mile south of the town, on the road to Birmingham, where it is exceedingly hard and compact, and the indentations on the surface of the pebbles where they have been in contact are very marked. It also appears at Beaudesert and Brereton, near Rugeley, in the north-west corner of map 62 N.E., and the only circumstance worth notice in connection with it is, that here the Lower Keuper Sandstone rests directly upon it, without the Upper red and mottled sandstone which usually occurs between.

On the east side of the Warwickshire coal-field there is only one part where the conglomerate can be seen, about one mile to the east of Polesworth; and in the Trent Valley Railway, about a mile to the south-east of Polesworth station, a very good section of it is exposed. Further north, at Bury Hill, near Waverton,

and in a cutting in the lane between Polesworth and Waverton on the east side of the railway, the junction between the conglomerate and the Permian rocks can be seen. Its total thickness here is about 250 feet, from which it will be seen that it has rapidly thinned away between this point and the neighbourhood of Lichfield.

C. Upper Red and Mottled Sandstone.—This subdivision of the Bunter beds rests upon the conglomerate. It is generally a very soft red sand, without any trace of pebbles, and forms a very distinct horizon in the New Red Sandstone between the Conglomerate and the Lower Keuper sandstone. It is not constant over the whole district, and thins rapidly away from the west to the east, and on the east side of the Warwickshire coal-field it is entirely absent.

In the neighbourhood of Birmingham and Lichfield this subdivision can be well seen; at the former town in the cemetery on the west side of the town, and also at Aston. From this point it strikes northwards to Sutton Coldfield. By referring to Section No. 2, Pl. 2, and the Horizontal Sections No. 1, Sheet 49, its position at this point between the Conglomerate and the Lower Keuper Sandstone will be seen. North of Sutton Coldfield this subdivision is cut out, and thrown down on the east under the Lower Keuper Sandstone by a fault, which brings the latter formation against the Conglomerate.

The next place where we find upper red and mottled sandstone is about 2 miles east of Aldridge, at Little Aston Hall and Mill Green, resting upon the conglomerate. It is, however, at Ogley Hay, about a mile south of Hammerwich, that this sand is best seen, where it is worked extensively, and used in South Staffordshire for forming moulds for castings. The thickness of this subdivision is about 200 feet in the district which has been described.

On the west side of the Warwickshire coal-field we have no evidence whether either of the subdivisions of the Bunter series exists, the Lower Keuper Sandstone and Keuper Marls being always brought against either the Coal-measures or the Permian rocks by faults, and we therefore never obtain a complete succession of the formations. It is therefore quite uncertain if the conglomerate and red sandstone continue underneath the Keuper marls and sandstone up to the coal-field, but if so they are probably of much less thickness than they are found further to the west.

It has been already shown that on the east side of the Warwickshire coal-field the conglomerate has only been found at one point, and the red and mottled sandstone is known not to exist here, for we find in the railway cutting near Polesworth, the Lower Keuper sandstone resting immediately on the conglomerate. From the preceding remarks it will be seen that the Bunter beds which attain a thickness of nearly 600 feet at Birmingham and Lichfield, thin rapidly away towards the east, till at the south end of the Warwickshire coal-field, they entirely disappear, and the Keuper beds rest directly on the Carboniferous and Permian strata.

B. Lower Keuper Sandstone or Waterstones.

The Lower Keuper Sandstone, which here forms the next division of the New Red Sandstone series in ascending order, consists generally of beds of white, red, and brown sandstones, with thin bands of red and mottled marls interstratified.

The sandstones often show ripple marks and much false bedding, and from this circumstance and the footmarks, and other remains found in them, some of these strata were clearly accumulated by the shore.

This division is constant over the whole of this district, both in thickness and in lithological character, and forms a very marked horizon between the subdivision of the Bunter beds last described and the Keuper Marls into which it passes. In the western portion we first find the Lower Keuper Sandstone at Birmingham, where its lower boundary is rendered rather obscure by the Drift, but its position as laid down on the map is probably nearly correct. From Birmingham it strikes northward to Sutton Coldfield, the west side being a fault bringing the Keuper marls which rest upon it to a lower level than the sandstone. A section of the sandstone may be seen by the side of the canal near Gravelly Hill, between Birmingham and Erdington, and further north near Sutton Coldfield, there is a good section exposed at Reddicap Hill, showing the passage of the Lower Keuper sandstone into the marls, the fault which forms the boundary further south having died away. Along the whole of this distance it maintains an average breadth of from half a mile to a mile, and has a general dip to the east of about 5°. The thickness at Sutton Coldfield, as shown in Horizontal Section, No. 1, Sheet 49, is about 200 feet.

About 2 miles north of Sutton Coldfield the Lower Keuper sandstone is cut off by a north-east and south-west fault, bringing it against the conglomerate, and a small inlier of the sandstone is exposed by the denudation of the Red Marl at Ash Furlong, about $1\frac{1}{2}$ miles north-east of Sutton Coldfield.

In the neighbourhood of Lichfield these beds are well developed, and on account of their almost horizontal position they spread over a large area of the country. They are well exposed at the village of Stowe, and also in many quarries in the vicinity, and a very good section, from almost their junction with the soft red and mottled sandstone to their uppermost beds, can be seen in a cutting in the South Staffordshire Railway at Hammerwich, where the lowest beds are slightly conglomeritic, and sometimes calcareous.

It will be seen by referring to the map that there is a large outlier of these beds about 2 miles south of Lichfield, surrounded on all sides by faults. There is no doubt that they belong to the Lower Keuper sandstone, for they can be seen in quarries at New Barr, and near Sheetway House, consisting of white sandstone, with bands of red marl; in fact, possessing all the usual characters so constant in these Keuper strata throughout the whole of the Midland Counties, from the Malvern Hills to Lan-

cashire and Derbyshire. It is, besides, on the north overlaid by a patch of red marl, (seen in pits,) with which the sandstone is always associated. This outlier, though somewhat obscure, appears to be surrounded on all sides by the Bunter beds, and the only explanation that can be offered as to its position here is, that it has been let down by faults.

The Lower Keuper sandstone forms almost a continuous belt round the Coal-measures and Permian rocks of the Warwickshire coal-field, and its occasional absence may always be accounted for by some fault which has brought the Red Marl against the older rocks.

In the north part of the coal-field near Tamworth we find these beds faulted against the Coal-measures. They are partly a calcareous breccia or conglomerate, and were formerly quarried about a mile south of Tamworth, on the road to Two Gates. The same calcareous beds can be seen on the road at Bole Hall, dipping to the north-west at an angle of 6° , and also in a quarry about three-quarters of a mile east of Amington Hall.

On account of the fault which brings the Lower Keuper sandstone against the Coal-measures near Tamworth, we are unable to tell with accuracy its thickness at this point, but it is probable that it would be found to be about the same thickness as in the neighbourhood of Lichfield and Sutton Coldfield, viz., 200 feet. By referring to Section No. 1, Pl. 1, and to Horizontal Section No. 1, Sheet 48, the position of these beds as they are brought against the upper Coal-measures at Glascote will be seen, and also the way in which they extend under the Keuper marls to the west, till they are brought against the conglomerate of the Bunter beds near Hints.

South of Tamworth the Lower Keuper sandstone is obscured by the Alluvium of the river Tame, and still further south it is thrown down by the boundary fault of the coal-field, and the Keuper marls are brought against the Coal-measures, although there is no doubt that we should find the Keuper sandstone beneath the marls. The probable position of the Lower Keuper sandstone will be seen by examining Section No. 2, Pl. 1, and the Horizontal Section No. 1, Sheet 49, which crosses the boundary near Kingsbury. Following the boundary fault further south, we find the sandstone cut out, by the Keuper marls being brought against the Coal-measures and Permian rocks. At Maxtoke, on account of the fault becoming less, a narrow strip of the white sandstone is exposed, rising from beneath the Red Marl on the west, being faulted against the Permian rocks on the east. The white sandstone further south is exposed in quarries in the grounds of Meriden Hall, and may be traced uninterruptedly to about a mile north of Kenilworth, where it is again cut out by the fault bringing the Keuper marls against the Permian strata.

We will now return to the north end of the coal-field, and follow these beds from north to south on the east side of the Coal-measures and Permian rocks. At Shuttington they are brought against the upper part of the Coal-measures by a north-west and south-east fault, which forms the surface boundary of the coal-

fields. East of this they occupy, together with the Keuper marls, a great part of the country between Shuttington and the Moira coal-field. Their position between the two coal-fields will be seen by referring to the Horizontal Section No. 2, Sheet 49.

Numerous sections of the Lower Keuper beds can be seen at Seckington, where the sandstone has been extensively quarried, and also at Newton Regis the white sandstone crops out to the surface. At the village of Austrey sections can be seen showing the gradual passage of these beds into the Keuper marls, and further south at Waverton or Warton the same beds are largely quarried for building stone.

South-east of Shuttington these strata are brought in succession against the Permian strata at Bramscote Hall, and the Conglomerate of the Bunter beds east of Waverton, by the same fault which brings the Keuper sandstone against the Coal-measures at Shuttington. Further south, at Dordon, the same beds are again brought against the upper part of the Coal-measures by the boundary fault of the coal-field. For the space of rather more than half a mile the marl is then thrown against Coal-measures, and underlying it the sandstones again appear in Merevale Park, near Atherstone, faulted against the lower unproductive Coal-measures by the same dislocation.

Between Atherstone and Nuneaton the Lower Keuper beds do not appear at the surface, the marls being faulted against the Carboniferous rocks; but they again crop out at Nuneaton, in Wash Lane, where they lie unconformably on the inclined strata of Millstone Grit and lower unproductive Coal-measures. This unconformity may be very well seen in the large quarry at Marston Jabet, a sketch of which by Professor Ramsay is given in the accompanying figure.

Fig. 4.



A Lower Keuper Sandstone.

B Coal-measure Shale.

C Greenstone.

We have here the lower unproductive Coal-measures, consisting of beds of shale (B), with intrusive beds of greenstone (C), dipping to the east at an angle of 15° , and at the top of the quarry the Lower Keuper white sandstone (A), which becomes a fine conglomerate at the base, is overlaid by a bed of red marl about 3 feet thick, the whole lying quite horizontally on the inclined edges of the shales and greenstones which crop up against it.

Further south, at the Wykin colliery, this unconformity has also been proved. By referring to the published Sheet No. 21 of the Vertical Sections of this coal-field, it will be seen that in the Wykin colliery, Section 5, they first went through a series of beds 75 feet thick, consisting of white sandstone and red marl interstratified. These beds were lying quite horizontally, and beneath them were found beds of red sandstone, purple and blue marls, and last of all the productive Coal-measures dipping nearly due west at an angle of 21° . It was mentioned in a note in the original section at the colliery, that the red sandstones and marls dipped nearly the same as the coals, and I think it most probable that they belong to the Permian strata, which are nearly and in some cases quite conformable to the Coal-measures in this district.

The same unconformity of the Lower Keuper beds on the Coal-measures was found in sinking the shaft at the Craven Colliery, where they went through 63 feet of white sandstone with red marl partings, lying quite horizontally before reaching the Coal-measures which dip to the west at a high angle.

From Wykin the Lower Keuper sandstone, generally from a mile to two miles in width, may be traced uninterruptedly to Leamington and Warwick, lying quite unconformably on the Permian strata, for while at Wykin and near Coventry it rests on the basement beds, passing southward it gradually creeps across the strata, and between Warwick and Kenilworth lies on the highest known Permian beds of the district.

In the neighbourhood of Warwick the sandstone has been extensively quarried for building stone, and also at Leek Wootton, Emscote, and Cubbington Heath. It was in this district that the footprints and other labyrinthodon remains were found which induced the late Dr. Buckland to place these sandstones in the lower division of the Keuper series. The bones found chiefly consisted of fragments of upper and lower jaws, vertebrae, ribs, &c., and according to Owen indicate five species, *Labyrinthodon giganteus*, *L. leptognathus*, *L. pachygnathus*, *L. scutulatus*, and *L. ventricosus*.* It has been already shown that the *Labyrinthodon* (*Dasyceps*) *Bucklandi* found near Kenilworth is a Permian species, although in published lists it has always been erroneously ranged with those of the Trias named above.

On the east side of the town of Warwick, the Lower Keuper sandstone is terminated abruptly by a north and south fault,

* Trans. Geol. Soc., 2nd series, vol. 6.

which brings the Red Marls against it and the Permian strata in a long straight line. This fault being a downthrow on the west, throws the white sandstone considerably to the north, and about a mile north of Kenilworth Castle we find the same beds rising from beneath the Red Marl on the west.

A. Red Marl and Upper Keuper Sandstone.

This division of the New Red Sandstone series succeeds the Lower Keuper sandstone, and is the highest portion of the Keuper beds. In this district it attains a maximum thickness of about 600 feet, and consists principally of red and mottled marls, with interstratifications of thin beds of green marl and sandstone. These sandstones vary much in thickness, sometimes being several feet and in some places only a few inches thick, and not unfrequently they thin away altogether.

They were first described by Sir Roderick Murchison and Mr. Strickland (Trans. Geol. Soc. vol. 6) as occupying a distinct horizon in the Keuper marls in Worcestershire and some parts of Gloucestershire. In this district, however, east of the coal-field and the Permian strata, these sandstones are in general not sufficiently developed in any one particular horizon to enable them to be laid down with certainty on the map for any great distance. At Orton-on-the-Hill, in geological map 63 N.W., between Polesworth and Ashby, there is a bed of white sandstone interstratified with the Red Marls, from 20 feet to 30 feet thick, which forms the crest of the hill at the village of Orton, but it cannot be traced for more than six miles to Salt Hill on the north, and the village of Sheepy on the south, where it seems to thin out. There are, however, numerous thin bands of greenish white micaceous sandstone (called "skerries" by the miners) throughout the whole of the marl, and it is probable that the beds at Orton Hill are formed by a local thickening of some of these bands, for they lie at a much lower horizon than those mentioned by Sir Roderick Murchison and Mr. Strickland, between Henley-in-Arden and Warwick, presently to be described.

On the north-west side of this coal-field, north of Lichfield, the Keuper marls occupy the valley of the Trent and the Tame. At Tamworth they form a narrow neck between that town and Hopwas Hayes Wood, being brought against the conglomerate beds of the Bunter and the Permian strata on the west, and the Lower Keuper sandstone rising from beneath them on the east. Further south they gradually widen and occupy a greater part of the area between the two coal-fields, the eastern boundary being faulted against the Coal-measures and Permian strata between Dosthill and the neighbourhood of Maxtoke. Southward from Maxtoke to the London and Birmingham Railway near Berks-well, the Lower Keuper sandstone is in juxtaposition to the Permian strata; and from thence, with a small exception near Kenilworth, the marls are again faulted against Permian beds as far as Goodrest Lodge, after which by a continuation of the same

fault, they abut on the Lower Keuper sandstone as far as Warwick. West of the country between Warwick and Tamworth, the marls extend as far as Birmingham and the neighbourhood of Sutton Coldfield, where the Lower Keuper sandstone previously described rises from beneath them.

South of Birmingham, the Keuper marls occupy nearly the whole of the quarter sheet 54 north-east, and attain a thickness of nearly 600 feet. It is in this map in the neighbourhood of Henley-in-Arden that the Upper Keuper sandstones, which lie in these marls are principally developed in this district, being from 15 feet to 25 feet thick. Their position is about 250 feet below the lowest bed of the Lias, and they are separated from the Lower Keuper sandstone by about 350 feet of red marl.

Sections of this zone of sandstone can be best seen in the rising ground immediately to the east of Henley-in-Arden, and at Liveridge Hill about a mile and a half north of the same town, where a deep cutting has been made for the purpose of lowering the road. It also occurs at Mouse Hill near Tanworth, Lapworth Hill, Rowington, Wroxhall, Shrewley Common, and Pinley Hill near Claverdon. At all these places it is the same sandstone, and the strata lying almost horizontally, the sandstone winds about, following the contours of the hills, and maintaining an average thickness of from 15 to 20 feet. The whole of this thickness is not, however, solid sandstone, but consists of white micaceous layers separated by bands of green marl. The best sections can be seen in the Canal cuttings at Shrewley Common, and the village of Rowington. At the former place we have the following beds exposed on each side of the tunnel, the strata lying nearly horizontally :—

	FT.	IN.
Red marl - - - -	30	0
White sandstone and green marl -	20	0
Red marl - - - -	10	0

On the opposite side of the valley which runs from Wroxhall to Lowsom Ford, the same beds are exposed in the Canal cutting at Rowington, where they cap the hill stretching south from that village to Finwood Green. The section here is the following :—

	FT.	IN.
White sandstone and green marl -	20	0
Red marl - - - -	40	0

At both these places the shells of the small bivalve crustacean *Estheria minuta* occur plentifully in the sandstone and green marls, together with footprints of *Labyrinthodon*, fish teeth, and numerous so-called fucoidal impressions.

On the east side of the coal-field and Permian rocks, in the neighbourhood of Polesworth, the Keuper marls are seen resting on the Lower Keuper sandstone at Austrey, Waverton, and Grendon; and the passage from the one into the other is exceedingly gradual, the beds at the junction consisting of alternating bands of red marl and sandstone.

Further south, near Atherstone, the Keuper marls are brought against the lower part of the Coal-measures by the east boundary fault of the coal-field. Except for a short distance in Merevale Park, where the Lower Keuper beds lie between the fault and the marls, they continue faulted against the Lower carboniferous rocks as far as the north end of Nuneaton, where the Lower Keuper sandstone again appears, and the fault here continuing through the town, brings the marls against it. East of this the red marls extend to the limits of the map, generally lying horizontally, although very few sections can be seen, the country being much covered with Drift.

Several borings were made some years ago on the Lindley Hall estate, about four miles north of Nuneaton, in the hope of reaching the Coal-measures. The descriptions of the strata are rather vague, but though they went down a considerable depth, it does not appear certain that they got through the Red marl series. Some of the lower beds may, however, belong to the Lower Keuper sandstone. Subjoined is a section of the strata passed through in one of the deepest bores.

Boring at Lindley Hall near Nuneaton.

	FT.	IN.
1. Soil - - -	7	0
2. Red clay and marl - -	4	6
3. Mottled ground - -	2	6
4. Blue sandstone (Skerry) -	1	0
5. Marl and rock marl -	99	0
6. Blue sandstone - -	0	6
7. Blue binds - -	0	6
8. Hard blue rock - -	0	6
9. Rock marl and gypsum -	41	6
10. Hard blue rock - -	1	0
11. Marl and rock marl -	20	0
12. Hard blue rock - -	9	0
13. Mottled ground - -	9	0
14. Rock marl - -	66	6
15. Hard blue rock - -	2	6
16. Rock marl and gypsum -	59	6
17. Hard mottled rock - -	8	0
18. Peldon - -	0	6
19. Blue and mottled rock -	7	6
20. Rock marl - -	2	6
21. Hard blue rock - -	2	6
22. Rock marl - -	24	0
23. Hard blue rock - -	0	6
24. Mottled rock - -	5	6
25. Hard blue rock - -	4	0
26. Marl and rock marl -	15	0
27. Grey rock and peldon -	4	0
28. Dark red rock - -	2	0
29. Blue and mottled rock -	31	6
30. Rock marl and gypsum -	1	6
31. Blue bind and clunch -	9	0
32. Red and mottled rock -	17	6

			FT.	IN.
33.	Blue bind and clunch	-	8	0
34.	Rock marl and gypsum	-	7	6
35.	Mottled rock	-	8	6
36.	Brown rock with marl	-	10	0
37.	Rock marl	-	1	6
38.	Blue and mottled rock	-	11	0
39.	Brown sandstone	-	6	0
40.	Blue rock and smuts	-	6	6
41.	Mottled rock	-	8	0
42.	Blue rock with partings	-	3	0
43.	Blue clunch	-	0	6
44.	Mottled rock	-	6	6
45.	Peldon	-	1	6
46.	Red and mottled rock	-	19	0
47.	Blue bind	-	1	6
48.	Red and mottled rock	-	10	6
49.	Hard blue rock	-	2	0
50.	Red sandstone	-	18	0
51.	Mottled rock	-	13	6
52.	Blue rock and bind	-	1	6
53.	Mottled partings	-	1	9
54.	Peldon	-	0	6
55.	Red and blue rock	-	14	3
56.	Blue binds	-	1	6
57.	Red sandstone	-	3	6
58.	Blue binds	-	4	6
59.	Peldon	-	2	6
60.	Brown rock	-	1	0
61.	Rock marl	-	3	0
62.	Brown rock	-	4	0
63.	Rock marl and sandstone alter-	nately	24	6
Total			660	0

South of Nuneaton the lower boundary of the Keuper marls strikes in a southerly direction, the Lower Keuper sandstone rising from beneath them on the west, the whole having a gentle inclination towards the south-east. The boundary between the marls and the Lower Keuper sandstone continues south, passing east of Coventry to Leamington and Warwick, where it forms a junction with the same marls, which have been previously described, on the west of the coal-field, extending towards Birmingham.

East of Leamington and Coventry they extend as far as the escarpment of the Lower Lias limestone and clay, which commences about six miles east of Leamington, and strikes in a north-easterly direction across the quarter sheet 53, N.W.

From the preceding description of the New Red Sandstone series included within this district, it will be seen that it may be divided into four subdivisions, as shown in the Table, page 34. We have also seen that all of these subdivisions are not constant over the whole of this district; that the Bunter beds gradually thin away from north-west to south-east, till in the neighbourhood of Bed-

worth or Coventry, and generally on the east side of the Warwickshire coal-field, they altogether disappear, and the Keuper beds rest directly on the Coal-measures and Permian strata.

Although a considerable portion of the rocks between Coventry and Kenilworth were formerly classed as New Red Sandstone, we have also seen that both on lithological and palæontological evidence there is a most marked difference between the two formations; that the New Red Sandstone is decidedly unconformable on the Permian strata, and that by these means we have been enabled clearly to define the boundary between them.

LIAS.

With the exception of two or three small outliers which occur to the west of Warwick and Kenilworth, in quarter sheet 54 N.E., the whole of this formation within the limits of the district to which this memoir refers, lies to the east of Leamington and Coventry, in quarter sheet 53 N.W.

Commencing on the south at Long Itchington, about six miles east of Leamington, the escarpment of the Lower Lias may be traced in a north-easterly direction across this sheet to about one mile north of Harborough Magna. The boundary between the Keuper marls and the Lower Lias is very clear and defined between Long Itchington and Stretton-on-Dunsmore, but further north it is much obscured by drift. The transition from the one formation into the other is very gradual, the Keuper marls passing upwards into green marls and clay, with a thin course of sandstone. Above this we get the lowest limestone beds, consisting of loose rubbly white limestone, which pass up into beds of blue limestone interstratified with bands of blue shale or clay, which are extensively wrought in open quarries about two miles east of Long Itchington, Church Lawford, and Newbold-upon-Avon, near Rugby. The limestone, when burnt, has long been celebrated as forming the finest cement for hydraulic purposes.

The outliers of the Lower Lias which occur in quarter sheet 54 N.E. are two in number, the largest of which is at Knowle, being about two miles in length and half a mile in breadth. It lies almost in the centre of the basin or trough of Red Marl between Warwick and Birmingham. The distance of this outlier from the nearest point of the main body of the Lower Lias is about 15 miles.

The other outlier is considerably to the south of the last, near Morton Bagot, about three miles south-west of Henley-in-Arden.

CHAPTER V.

IGNEOUS ROCKS AND FAULTS.

THE igneous rocks comprised within the district to which this memoir refers are all of one kind, viz., Greenstone, composed of felspar and hornblende. It is not so certain, however, whether they all belong to the same period; and it is only to those which are contained within the limits of the Carboniferous rocks, where they come to the surface, that we are enabled to assign any geological date, and to ascertain the details of their mode of occurrence.

The other Greenstones to which I refer as not being within the coal-field, form three hills on the north-east side of the Geological Survey map 63 S.W. Two of these are close together, the largest one being about three-quarters of a mile in length and half a mile broad near the village of Sapcote, and the second immediately to the north of the last at Stony Stanton. The third is about two miles north of Stony Stanton at Barrow Hill, near Potters Marston. They do not form high or abrupt hills, but rise through and slightly above the plain of the Keuper Marls, by the denudation of which they have been exposed. These, where in contact with the Greenstone, are not altered or disturbed in any respect, but lie nearly horizontally on its uneven surface, and fragments of the Greenstone, often slightly water-worn, occur in the marls at most places where a junction between the two rocks can be seen. From this it is clear that these Greenstones are certainly older than the New Red Marl; but whether they belong to those which occur among the Cambrian rocks of Charnwood Forest, or to those in the Coal-measures of Warwickshire, is doubtful, as at no place can their junction with any other rocks but the Keuper Marls be seen. From their position, however, with regard to the Cambrian rocks of Charnwood Forest, and their resemblance to some of the igneous rocks on the north-east end of it, it is considered most probable that under the New Red Marl they may be surrounded by Cambrian strata.

The igneous rocks that occur within the coal-field are intrusive, and most probably all belong to the same period. The district where they are principally developed is between Atherstone and the neighbourhood of Bedworth, in the lower Coal-measures and the Millstone Grit. On and near Hartshill there are ten distinct lines of Greenstone, all of them intrusive, altering the sedimentary rocks in contact both with their upper and under surfaces. Many of these can be traced in a continuous line on the surface for four or five miles, and one in particular can be followed continuously for nearly eight miles, commencing in Merevale Park near Atherstone, and terminating at Marston near Bedworth. Along the whole distance some of these lines of greenstone occupy the same horizon, running parallel with the beds of the Coal-measures between which they have been injected. In some cases, however,

they do not precisely follow the lines of bedding, but run in straight lines, passing gradually from lower into higher beds, without any direct reference to the stratification of the rocks with which they are associated.

Wherever a junction between the igneous and the sedimentary rocks can be seen, the beds in contact, both above and below the Greenstone, are invariably altered; and this, added to the fact that some of them break slightly across the lines of bedding, proves that though they generally appear to be bedded traps, and might at first sight be mistaken for lavas poured out during the deposition of the Coal-measures, they have in reality been injected between the beds after the lower Coal-measures were formed.

The phenomena connected with these rocks can be well observed in some of the quarries in the Millstone Grit between Nuneaton and Hartshill, and also in the lower part of the Coal-measures wherever a section is exposed. The most important of these I will now proceed to point out, commencing in the Millstone Grit.

The Greenstone, which is laid down on the map between the lowest exposed bed of the Millstone Grit and the eastern boundary fault of the coal-field, is rather obscure, and is only seen in one or two places, but never in contact with the grit; and it is only inferred to be intrusive in the same way as the others, on account of the altered character of the rock which lies immediately above it. The best place where this Greenstone can be seen is in an old quarry in a field on the south-east side of the road which runs from Caldecote windmill to Caldecote Wood, and with diligent search it can be traced by fragments through the fields on each side of this old quarry, more particularly at Caldecote Hill, and where the public road between Nuneaton and Atherstone crosses the trap I found fragments thrown out from the ditches on either side.

The next greenstone above this can be seen in the quarries near Hartshill. It is of no great extent, and is about 4 ft. 6 in. thick, lying between beds of very hard and compact quartz rock. The other intrusive bed which occurs in the grit can be well seen in a quarry by the side of the canal at Barr Green near Nuneaton. It can be traced from this point in a continuous line to within a mile and a half of Atherstone, where it is cut off with the other rocks by the fault which brings the Keuper Marl against the lower Carboniferous rocks. This line of Greenstone does not continue in the same horizon in the sedimentary strata the whole distance, but at Hartshill branches out of the Millstone Grit into the shales which lie above it.

In the neighbourhood of Merevale near Atherstone the trap rocks occur in large masses, and from the contorted appearance of the strata with which they are associated, the idea is suggested that this might possibly have been close to the point of eruption. The largest of these masses occurs in Merevale Park, and forms the high ground near Merevale Hall, the residence of W. S. Dugdale, Esq. This mass of Greenstone has rather an irregular outline, and

the sedimentary rocks in contact with it are much altered and contorted. At the southern extremity two lines or dykes of trap branch off from it, injected in the lines of bedding of the lower part of the Coal-measures, and one of these dykes can be followed for a distance of three miles, passing through Hopwood Coalwood, and the Reservoir near Oldbury, and Oldbury Hall to Nuneaton Common.

Another dyke of greenstone occurs immediately above Merevale church, and it can be seen in a quarry where the first "o" in the Black Pool is marked on the map. It is a hard compact basaltic-looking rock, weathering brown. In a quarry by the side of the lane between Merevale Church and Baxterly Common the shales in which the greenstone has been injected are seen to be much contorted and altered by heat.

In the east part of Merevale Park, and in Atherstone Outwoods, numerous other dykes can be seen, and from these proceed the long lines of trap which have been before described as running in the line of bedding of the shales of the lower part of the Coal-measures through Hartshill Hays.

Three of these lines of Greenstone can be well seen in the lane which runs on the south-east side of Purley Parks. On account of the softness of the shales with which they are associated the space between the outcrop of each dyke of trap is often a depression, and the dykes form ridges, by which we are enabled to trace them in a continuous line on the surface for a considerable distance. This occurs more especially between the places marked on the map Raspberry Knob and Common Barn, near the large reservoir at Oldbury, where the outcrop of each dyke is distinctly marked by a ridge formed by the denudation of the soft shales with which they are associated.

About a mile east of Ansley Hall, near Moor Wood, there is a dyke of greenstone which terminates in a large mass, forming an oblong-shaped hill, but stretching toward the south-east in the form of a thin intrusive bed till it dies away near Chapel End. The junction between this dyke and the shales can be seen close to Moor Wood, which shows the sedimentary rocks in contact with it to be exceedingly altered. Another junction is visible close by the side of the brook which runs east from Haunch Wood, about a mile west of Nuneaton, where in the same quarry the actual junction of the Greenstone with the shales both above and below the igneous rock can be seen, showing both to be altered in the same manner.

In the Railway cutting near the Chilvers Coton station four distinct dykes of Greenstone lying between the strata are cut through and exposed in a very clear section, the whole of them altering the rocks with which they are in contact both above and below. One of these dykes is a continuation of that which commences in Atherstone Outwoods, and can be traced still further south as far as Marston Jabet near Bedworth, where it is extensively wrought, being used for the purpose of paving the streets in towns. In this quarry we find good evidence of the intrusive character of

these traps. Here there are two beds of Greenstone, separated by a few inches of shale, which is excessively altered, and the shale, which lies on the uppermost bed of trap, is also hardened, and as it were porcelained at the junction.

The precise geological date of the intrusion of these lines of Greenstone is uncertain. Though they lie exclusively in the lower unproductive beds, they were probably injected after the deposition of the upper strata of the Coal-measure series, and perhaps even later than the formation of the Permian rocks. This at least seems certain, that having been mostly injected between the beds (and being thus, as it were, *interbedded*), far from having caused the disturbance, they have themselves been subjected to those movements that bent the Coal-measure and Permian rocks into the form of a basin. These were disturbed and denuded before the deposition of the New Red Sandstone, and as the faults which throw down the latter round the confines of the former two, cut off alike both Permian and Coal-measure beds with the included lines of Greenstone, it seems likely that the intrusion of the igneous bands preceded the deposition of any part of the New Red Sandstone.

The only other mass of trap rock which remains to be mentioned occurs at Dosthill, about two miles north of Kingsbury, on the west side of the coal-field. It is an ordinary Greenstone, composed of felspar and hornblende, often much decomposed, and weathering brown where exposed to the atmosphere. There is no doubt that it is intrusive, and that the eruption took place after the deposition of the Coal-measures, for we find the rocks on the east side of the trap, not only where in contact, but for a considerable distance from the actual junction, much altered and porcelained in the same way as at Marston quarry near Bedworth, and the lowest coal, the crop of which runs along the east side of the trap at Dosthill, was found to be burnt and rendered useless in its immediate vicinity.

Faults.

The faults affecting the interior of the coal-field are neither numerous nor of any great extent. Those which form its boundaries on the east and west are the largest. Two faults of considerable amount lie in the north end of the coal-field, both of which have been proved in the old colliery operations at Kettlebrook. They are downthrow faults, on opposite sides forming a trough of coal in the centre, the most easterly having a downthrow to the west, the amount of which was proved in Kettlebrook colliery to be 26 yards. The same fault has also been proved further north at Glascote colliery, but the amount of "throw" there has not been ascertained, no workings having yet been carried on to the west of it. The other fault, which runs nearly parallel to that last described, was also proved in the old workings at Kettlebrook, and was found to be a downthrow to the east of 18 yards. By referring to the map 62 N.E. the

direction of these faults will be found accurately laid down as far as the small scale of the map will permit; and in Section No. 1, Pl. 1, and Horizontal Section No. 1, Sheet 48, the position in which the coals are thrown by these faults will be seen. They run parallel to each other and also nearly parallel to the western boundary fault of the coal-field.

The western boundary fault must be of very considerable amount, but it has only been proved at one point, viz., at the Park Collieries, where the coal was wrought up to the "Red rock fault." This fault can be traced in a continuous line for 20 miles, having on the average a north and south direction. In the map 62 N.E. it commences near Seckington, the Keuper Marls being faulted against the Lower Keuper Sandstone. Following the line to the south-west the Keuper Sandstone is faulted against the Coal-measures, and this continues to near Fazeley, where the fault takes a more southerly course to Dosthill, at which place the trap of Dosthill lies alongside it. Between Dosthill and Fazeley it is obscured by the alluvium, but south of Dosthill it passed east of Cliff, the Keuper Marls being brought at this place against the lower part of the Coal-measures and continuing thus as far as Flanders Hall, south of which the fault is between the Permian rocks and the Keuper Marls, and Lower Keuper Sandstone near Meriden.

I have laid down a fault in the map 62 N.E., having an east and west direction, running between Two Gates and Polesworth. I have no decided information of this fault, and have only put in a dotted line, although it is certain that in working the Seven-foot coal in Kettlebrook Colliery toward Wilnecote they came upon some troubled ground, but I could get no accurate account of its course. The small outlier of Permian beds seems to be affected by this fault, and I have laid it down as indicated in the map.

The eastern boundary fault of the coal-field commences near Shuttington, where it is cut off on the north end by the western boundary fault just described. The Lower Keuper Sandstone is here brought against the upper part of the Coal-measures. East of Shuttington the fault seems to divide into two, and one branch forming the boundary of the coal-field, takes a course directly south, passing Polesworth about half a mile to the east. This fault was proved in the old workings near Polesworth station, the coals being wrought up to "the Red rock fault" and there entirely cut off. Further south near Dordon the coals were partly wrought at the outcrop dipping to the east, but were so much faulted that the workings were not proceeded with. South of Dordon this fault continues in a south-easterly direction, passing near Atherstone to Nuneaton, and it can be seen in a quarry in Merivale Park, the Lower Keuper Sandstone being brought against the lower Coal-measures; this continues to within a mile of Nuneaton, where the fault is between the Keuper Marls and Lower Keuper Sandstone, after which it is gradually lost in the marls.

The next fault of any importance affecting the coal occurs at Bentley Park and Monk's Park, near Atherstone and Ansley. Its

direction is about north and south, and the coals are thrown down to the west 19 yards, the whole of the coals on the west side of the fault being shifted considerably to the north. This fault was proved in the workings of the Four-feet coal at Oldbury, which coal was found to have been thrown down to the west 19 yards. The position of the fault further north was proved by numerous borings, all of which were on faulted measures. It also affects the Permian rocks in a similar manner, and can be seen in a quarry by the side of the lane between Monk's Park and Spodes Rough.

I think it very probable that the fault on the north end of the small patch of Coal-measures at Arley is a continuation of this 19 yards fault, although I have no actual proof of such being the case. The same inlier of Coal-measures appears to be affected by two more faults, one running north and south through Arley Wood, having likewise a downthrow to the west, and bringing the Permian rocks against the Coal-measures, and it is possible, as already stated, that this may be a continuation of the 19 yards fault. The ground, however, at this spot is much obscured by drift, which makes it difficult to lay down with accuracy the position of these faults, especially as there are no workings in the Coal-measures to assist in their determination.

I will now briefly describe the range of the other faults in this district which are known to affect the New Red Sandstone. One of the principal faults passes through Birmingham, commencing near Bromsgrove Lickey. At Birmingham it gradually becomes smaller proceeding north, and finally dies out towards Sutton Coldfield. Its direction is a little east of north, and at Birmingham and northwards the Keuper Marls are faulted against the Lower Keuper Sandstone.

Another very large fault, throwing down the Keuper marls against the Permian and Pebble beds, runs in a north-east and south-west direction from Tamhorn Park, three miles north-west of Tamworth, and crossing the Watling-street Road, near Hints, continues in a south-west direction to Canwell Hall. From Canwell Hall it takes a more westerly course towards Sutton Park, where it is cut off by a north and south fault. The evidence of the existence of this fault is exceedingly clear. The Conglomerate forms a high ridge between Tamhorn Park and Hints, and has a general dip towards the north-west; and the Keuper Marls, which are higher geologically than the Conglomerate, occupy the low ground between Hints and Tamworth, and have every appearance of being under it. This apparent reversal of the position of the divisions of the New Red Sandstone cannot be accounted for otherwise than by a downcast fault on the east, throwing the Keuper marls to a lower level than the lowest division of the New Red Sandstone in this district.

Another fault ranges north and south, forming a slight angle with the fault last described, which it meets in a point near Canwell Hall. It is a downcast to the west, on the south being between the Permian and New red conglomerate, and, as it proceeds north, bringing the Lower Keuper Sandstone against the

same conglomerate. This fault is cut off on the north end by another which runs at right angles to it, between Swinfen Farm and Femley Pits, a mile and a half south of Lichfield. It is a downcast on the south, throwing the Keuper marls and sandstone against the Bunter conglomerate.

Another fault, also running at right angles to the last, commences in the south near Shenstone, and ranges north towards Lichfield. It is remarkable that this fault, being a continuation of the Shenstone line of fault, shows a downthrow on the west, whereas towards Shenstone it is a downthrow on the east. The change in the direction of the throw seems to take place at the point where it is cut by the Femley Pits fault, which point seems to form an axis, beyond which, on the north and south, the tilting of the strata took place in opposite directions.

APPENDIX.

By T. H. HUXLEY, F.R.S., Professor of Natural History,
Government School of Mines.

1. *On Dasyceps Bucklandi (Labyrinthodon Bucklandi, Lloyd).*

At the meeting of the British Association in 1849 Dr. Lloyd, to whom science is so much indebted, as the collector and preserver of almost all the known remains of British Labyrinthodonts, gave a description and exhibited a lithographic drawing of a "new species of *Labyrinthodon* " from the New Red Sandstone of Warwickshire." An abstract of the description, without the figure, is published in the Reports of the British Association for 1849, p. 56; but it is very brief, the most important points being the indication of "projecting occipital condyles," and the statement that the teeth presented "the usual characters of the "genus." The fossil, which is named by Dr. Lloyd *Labyrinthodon Bucklandi*, is said to have been derived from the "Bunter sandstone," but the locality is not given.

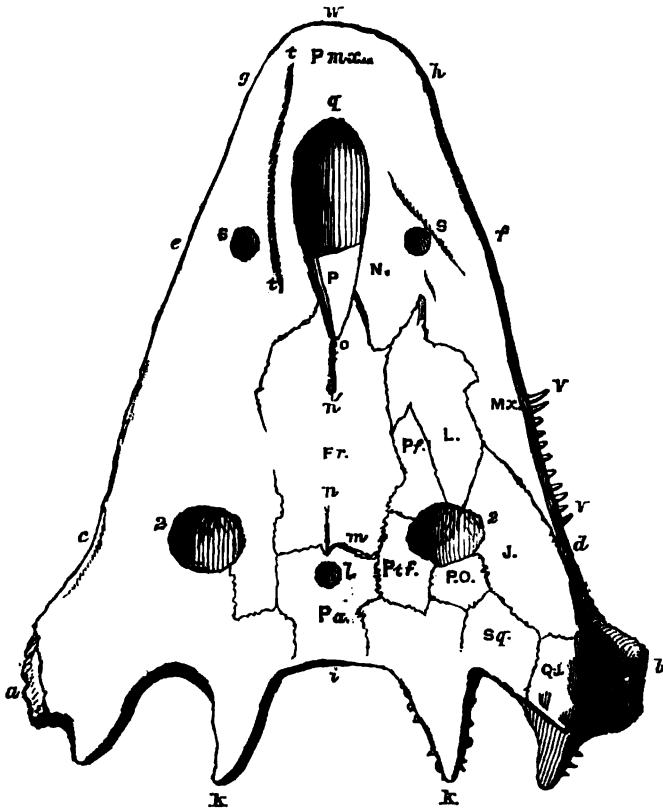
In the course of a hasty visit to the Warwick Museum during the past winter (1858), I was struck with the remarkable appearance of this fine fossil, and I saw at once that it was generically distinct from any known Labyrinthodont. Hence, having occasion to refer to it incidentally in a paper which I read before the Geological Society in March last, I proposed a distinct generic name, *Dasyceps*, for it; but I was not at that time aware of the fact that the quarry at Kenilworth, whence the fossil was obtained, is not situated in the Bunter at all, but in rocks of Permian age.* The knowledge of this circumstance lent additional interest to the inquiry into the precise characters of *Dasyceps*, which I undertook during a recent repetition of my visit to the excellent Museum at Warwick, where this and so many other important remains are stored up.

The flat cranium, which is ten inches in length from the middle of the occipital region to the end of the premaxillæ (Fig. 1, *i, w*), has

* See p. 32.

been so split that the upper wall remains attached to the one half of a block of sandstone, while the lower is imbedded in the other; consequently only the smooth inner faces of the cranial bones are for the most part displayed, though a portion of the frontal bones which adheres to the lower half of the cranium exhibits the upper or outer surface of those bones, and the character of this surface is well shown by the impressions which remain where the bony plates themselves have disappeared.

Fig. 1.



The upper half of the cranium is in better condition than the other. It has the form of an isosceles triangle, whose apex is abruptly rounded off, and whose base (the space between the outer edges of the quadrate bones, *a, b*, Fig. 1,) measures $9\frac{1}{2}$ inches. An inch and a half in front of the posterior margin of the occiput, on the line of the posterior margins of the orbits (*c, d*), the skull measures $7\frac{3}{4}$ inches in transverse diameter. Six inches and a quarter in front of the occipital margin, or on the line of the external nares (*e, f*) the transverse diameter of the skull is five inches. The postero-lateral angles (*a, b*), of the cranium are truncated, and in front of them the lateral contour sweeps inwards (*b, d*), and is then continued, in a nearly straight line, forwards to the obtuse end of the snout, which measures about $2\frac{1}{2}$ inches in width, half an inch behind its extremity (*g, h*). The strong postero-lateral angles of the cranium project for two inches behind the posterior margin of the occiput (*i*), which margin is interrupted, between its centre and these

produced postero-lateral angles, by two large and stout pointed processes (*k, k*), which project backwards for fully an inch and a half.

In the middle line, $1\frac{1}{2}$ inch in front of the occipital margin, or on a level with the posterior margins of the orbits, the bony substance presents a rounded parietal foramen (*l*) one-third of an inch wide. Just in front of it lies a transverse suture (*m*), separating the parietal from the frontal bones, which is slightly convex forward, and presents in the middle line a slight backward sinuation, whence a median suture (*n*) can be traced for a short distance forwards. At *n'* is what appears to be the anterior continuation of this suture, which terminates abruptly in a broad oval space (*o, p, q*), $3\frac{1}{2}$ inches long, and narrow behind, but gradually widening in front, till at $2\frac{1}{4}$ inches from its posterior extremity it attains a width of $1\frac{1}{2}$ inches. The contours of this space are symmetrically and evenly rounded, and where its surface has remained unbroken, as at (*p*), it is perfectly smooth, presenting in this respect a marked contrast to the strongly pitted impressions everywhere left by the adjacent facial bones.

The bony edges which form the boundaries of this area are, in fact, quite sharply defined, and I could nowhere find the least trace of their having been continued into the substance of the matrix which fills the area. I can only imagine, therefore, that, during life, a membranous, or at most cartilaginous, substance must have filled this interspace.

The orbits (*2, 2*), rounded spaces about an inch in diameter, are situated very far back, and are remarkably small in proportion to the size of the skull. They are placed about midway between the middle line of the skull and its outer margin. The round external nostrils (*s, s*) also proportionally very small, their diameter not exceeding half an inch, are in like manner situated very backwardly, their anterior margins being more than three inches from the end of the snout.

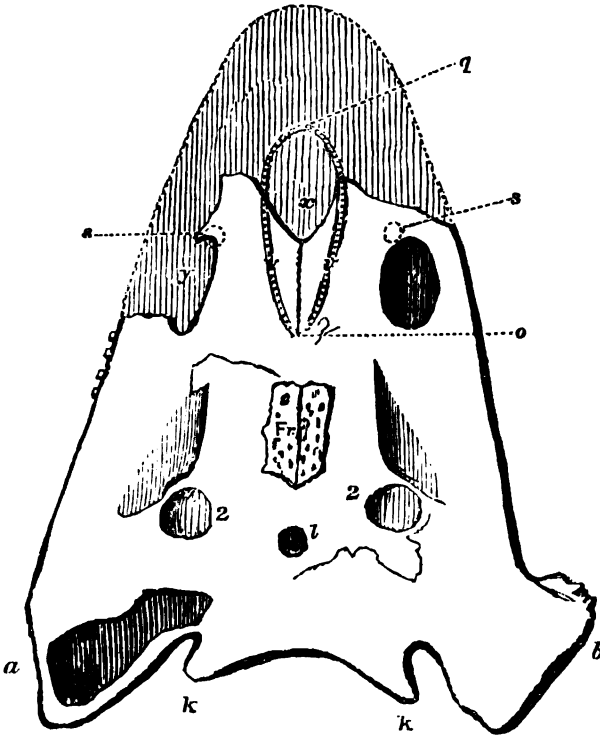
On the left side of the fossil (the right side of the skull) there is, between the nostril and the facial fontanelle (as the area *o, p, q*, may be termed) a sinuous elevation, *t, t*, which is probably the cast of a groove on the outer surface of the face, answering to the anterior of the so-called "mucous-canals" of the ordinary Labyrinthodonts.

Some of the cranial sutures can be traced with tolerable certainty; those in the neighbourhood of the orbits, for instance, between the post-frontal (*Pt.f.*), pre-frontal (*Pf.*), post orbital (*P.O.*), and jugal (*J.*) bones, are very well marked. The lachrymal (*L.*) appears to enter into the anterior boundary of the orbit, and the maxillary (*Mx.*) extends back to at least the point (*d*), if not further. The frontals (*Fr.*) seem to have been very large bones, extending from just in front of the parietal foramen to the posterior margins of the facial fontanelle, into which they enter. The bone which unites with them at this point I regard as the nasal (*N*). Its junction with the premaxillary (*Pmx.*) cannot be observed, but I have little doubt that the boundaries of the fontanelle are furnished by three bones on each side, the frontals, nasals, and premaxillaries. The characters of the supra occipital cannot be made out, nor are any sutures distinctly visible in the region between the letters *i, k, Sq*. The latter bone and that marked *Q.J.* are, it is to be understood, only provisionally denominated squamosal and quadratojugale, as I entertain some doubts respecting their homologies.

Dr. Lloyd (*suprà*) speaks of twenty teeth. The specimen is so excessively fragile that some of those which he observed may readily have perished. At any rate I can only find eleven, which occupy a space of two inches (*v, v*), on the left side of the maxilla, and of these only the two anterior ones are in a perfect condition. These teeth

are pointed, much curved, and about a quarter of an inch long, their bases having a diameter of three-fortieths of an inch. They are directed outwards, their curved sides being downwards and inwards (in the natural position). They are ankylosed to the margins of the jaw, which exhibits no alveolar groove. Their bases are longitudinally striated, and they present apparently a wide pulp cavity, but I can say nothing respecting their minute structure, as I did not feel justified in detaching any of the few which remain. Obscure traces of teeth are seen in the rest of the alveolar margins.

Fig. 2.



The inferior half of the cranium (Fig. 2) presents a small adherent patch of the frontals (*Fr.*), and what appear to be the under portions of the bases of the two processes *k, k*.* The matrix at *l*, and *2, 2*, presents impressions corresponding with the orbits and parietal foramen, but the most interesting portions of this half of the fossil are the broad bony plates *V, V*, separated by a median suture, and the wide, more or less completely circumscribed apertures *x, y, y*. Of these, *x* appears to be the anterior palatine foramen, whose anterior boundaries are broken away, while *y, y*, are the posterior nares. In Figure 2 I have dotted the outlines of the facial fontanelle (*q*) and of the external nostrils (*s*), so as to show

* I suppose that these are the parts regarded by Dr. Lloyd as the occipital condyles; their nature, however, appears to me to be what I have stated above. I could discover no condyles where I should have expected to find them; but it is possible that they might yet be brought to light by very careful excavation.

their relations to the apertures exhibited by the upper face of the palate, and it will be seen that the external nares are situated just in front of the line of the anterior margins of the posterior nares. No vomero-palatine or other sutures can be detected.

The relations of *Dasyceps* to the Labyrinthodonts will be clear to those who will compare Fig. 1 with Quenstedt's figure of the inner surface of the cranial bones of *Mastodonsaurus robustus* (Die Mastodonsaurier im Grünen Keupersandsteine Württembergs; 1850; Tab. 1, Fig. 1). With many differences, both *Mastodonsaurus* and *Capitosaurus* approach *Dasyceps* in the posterior situation and small size of their orbits, but the latter differs from these and from all other Labyrinthodonts with which I am acquainted, in the backward position of the external nostrils, in the existence of a "facial fontanelle,"* and in the magnitude and backward extension of the anterior palatine foramen. Add to these the characters of the teeth; the great size and posterior projection of the processes *k*, and the peculiarly rugose and almost spinulose sculpture of the surface of the cranial bones, and the generic distinction of *Dasyceps* from all other Labyrinthodonts appears to be fully justified.

The only other known Permian Labyrinthodont is the *Zygosaurs lucius* from the Cupriferous Zechstein of Russia, described by Eichwald in the "Bulletin de la Société Impériale des Naturalistes de Moscou," for 1848. It differs very widely from *Dasyceps*.

2. On a Fragment of a Lower Jaw of a large Labyrinthodont from Cubbington.

The original specimens of the large Labyrinthodont discovered by Dr. Buckland at Guy's Cliff, and described (from casts) by Prof. Owen under the name of *Labyrinthodon Jaegeri*, are, it would seem, lost; it is therefore fortunate that one of the collectors of the survey, Mr. Richard Gibbs, has obtained from the quarry at Cubbington, whence other Labyrinthodont remains have been obtained, a fragment of a mandible which must have equalled, if it did not surpass, in size the so-called *Labyrinthodon Jaegeri*.

This fragment consists of about $7\frac{1}{2}$ inches of the hinder part of the left ramus of a lower jaw, exhibiting the articular cavity and the coronary edge in a good state of preservation, while the lower margin is somewhat fractured, and the posterior extremity is broken away.

The articular cavity is $1\frac{1}{2}$ inches long by $\frac{3}{4}$ of an inch wide, concave from before backwards, slightly convex from side to side. Its posterior margin rises into an abrupt transverse ridge, while its anterior limit passes gradually into the coronoid edge. The anterior end of the fragment measures $3\frac{1}{2}$ inches in depth, and this measurement must nearly coincide with that of the jaw when perfect. The posterior part of the suture between the angular and the articular elements of the mandible is well displayed, as is the remarkable, strong process sent off inwards and upwards by the former bone.

The outer surface of the angular bone is deeply ridged and grooved, the sculpture appearing to radiate from a point situated near the lower margin of the bone and $3\frac{1}{2}$ inches in front of the line of the posterior edge of the articular cavity. Towards the upper or coronary edge

* This fontanelle would seem to correspond with the interspace left between the ascending processes of the premaxillary bones in the common frog.

of the ramus the pointed hinder extremity of the dentary bone is seen extending a little behind the level of this centre of radiation of the sculpture.

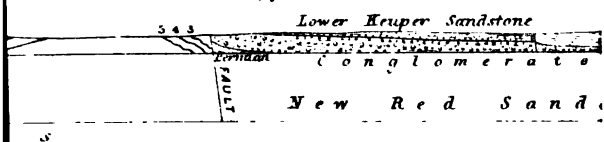
I may observe, that this and other Labyrinthodont mandibles which I have seen show that each ramus was composed of only three elements, a dentary, an angular, and an articular, the last being continued forwards along the upper and inner side of the ramus, nearly to the symphysis, and thus taking the place of a splenial bone. The posterior, inferior, and internal part of the angular element sends a strong process upwards and inwards, and between this process and the outer part of the bone the articular is wedged.

Judging by the proportions exhibited by other Labyrinthodont remains from the Warwickshire Trias, it is probable that the entire jaw of which this fragment formed a part was about two feet long.

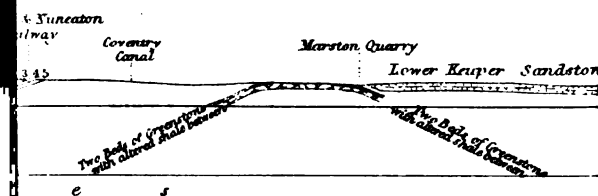
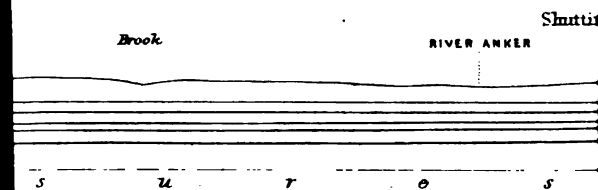
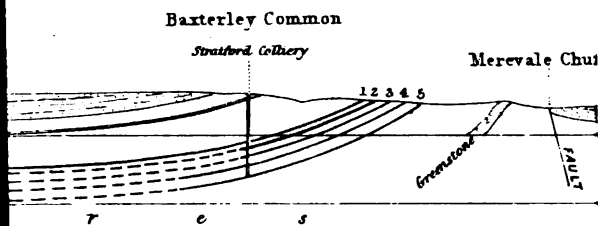
It is questionable whether more than one species of Labyrinthodont has been found in the English Triassic rocks; and the most perfect remains which have been obtained belong not to the German *Mastodonsaurus* (Jaeger), but to the perfectly distinct genus *Labyrinthodon* (Owen), which has been erroneously confounded with it. It is therefore quite possible, and even probable, that the mandible which I have just described may have belonged to a *Labyrinthodon* of large size, and not to *Mastodonsaurus Jaegeri*, with which, apparently merely on account of their size, the Guy's Cliff specimens have been identified.

In conclusion, I would caution geologists who are unacquainted with what has been done by Von Meyer and Plieninger, and others, towards elucidating the nature of the Labyrinthodonts, against supposing that there is any evidence whatever to show that the Labyrinthodonts were frog-like animals. All the positive evidence tends to show, on the contrary, that they were similar in form to the *Urodelæ Batrachia*, the salamanders and newts.

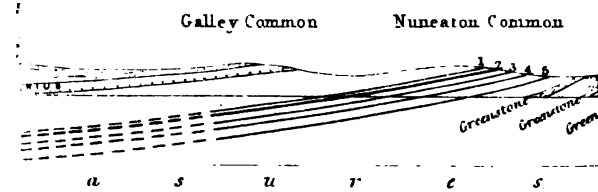
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